NASA CR-
144428

FINAL REPORT

ON DEVELOPMENT OF AN INEXPENSIVE, LIGHTWEIGHT THERMAL MICROMETEROID GARMENT FOR SPACE SUITS

Prepared Under
Contract NAS 9-14199

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For

National Aeronautics and Space Administration
Johnson Space Center
Houston, Texas 77058

ILC DOVER

CONTENTS

1.0 INTRODUCTION

A contract for the development of an inexpensive Lightweight Thermal Micrometeroid Garment (TMG) for space suits was awarded to ILC Industries, Inc. by the National Aeronautics and Space Administration on June 3, 1974. This contract required the delivery of two prototype Thermal Micrometeroid Garments as end items which has subsequently been accomplished. This document comprises the final report for the contract.

1.1 PURPOSE

The basic purpose of this effort was to develop a coverlayer for space suits that would be lightweight and inexpensive relative to those used on earlier space programs.

1.2 SCOPE

The scope of this contract was four-fold and was, therefore, divided into four phases of activity as follows:

1.2.1 Phase I: Initial activity in this phase was to survey industry for advancements in aluminized film technology; to thoroughly evaluate established TMG-related data; and to perform trade-off evaluations for the initial design of the shell spacer, film and liner layers. The results were assembled into a matrix report with recommendations for the most optimum candidates. This part of Phase I culminated in a review at NASA/JSC with the selection of materials for sample purchase. The second step of Phase I consisted of material procurement, cross section sample fabrication, material testing,

trouser fabrication (for in-use wear tests), and NASA flammability tests. Phase I was concluded with a Preliminary Design Review which selected materials for final procurement.

1.2.2 Phase II: This phase consisted of seams, attachments, and pattern design. This pattern design task included the fabrication of a single layer bulk mock-up and multiple layer mock-up section to verify the attachments and mobility functions. This phase terminated with the Critical Design Review at which time seam samples and final pattern mock-ups were presented.

1.2.3 Phase III: This phase consisted of the first prototype fabrication, Design Verification Testing at NASA/JSC and the second prototype fabrication.

1.2.4 Phase IV: This final report of all activities, evaluations, tests and data comprises Phase IV.

1.3 ACCOMPLISHMENTS

The lightweight aspect was approached by using minimum required cross-sections necessary for earth orbital mission, by utilizing the lightest weight materials possible and by decreasing the use of weight costly taping. A substantial reduction in costs was accomplished by simplifying manufacturing techniques thus reducing assembly time and by utilizing off-the-shelf materials.

1.4 CONCLUSIONS

The TMG cross sections developed in this effort represents the most lightweight and economical combination of fabrics currently available that will meet the basic design criteria. The new technique of wrapping the multiple layers for the circular elements of the garment has proven to be a significant labor savings factor.

2.0 TMG DEVELOPMENT PROGRAM

This program for the development of a lightweight, inexpensive Thermal Micrometeroid Coverlayer was implemented in four phases. The following is a chronological discussion of each phase.

2.1 PHASE I

2.1.1 Industry Survey

Initial activity during this phase was directed toward a survey of industry for advancements in aluminized films and spacer technology and to thoroughly evaluate established TMG related data. Details and conclusions of this survey are shown in Appendix A. A report of special fabrics considered was prepared, and a materials search was started to establish the final material candidates for the shell, liner, film and spacer layers of the TMG, see Appendix B.

2.1.2 Material Selections

During a review meeting at NASA/JSC the following materials were selected for purchase. A short discussion is presented with each selection.

2.1.2.1 Shell

Ortho-fabric, composed of Gortex, Nomex and Kevlar fibers was chosen for the shell of the TMG. The specimen displayed at the meeting had a warp count of 40 yarns per inch and a fill count of 80 yarns per inch. ILC proposed that the count be increased to 100 yarns per inch in the Gortex outer layers based on the trouser wear tests conducted at ILC-Dover and the flammability tests at NASA. These tests demonstrated the fabric was too permeable to air and liquids. NASA supported the suggested modification from the additional standpoints of abrasion and flammability and the 100 x 100 yarns per inch Gortex fabric was selected.

2.1.2.2 Film

Although three aluminized mylar and kapton films were assessed as most appropriate, the material finally chosen was an off-the-shelf nylon leno reinforced mylar film, available at a cost of less than $3.00 per square yard. It was agreed that film vent holes would not be necessary. This decision was based on a phone call with J. Poradek (NASA) who explained that the problem of residual gas is over-ridden by the additional thermal protection gained from non-vented films.

2.1.2.3 Spacer

Nomex scrim was selected as the spacer material. However, there was some question as to its necessity in the TMG cross section. Subsequent tests showed that little or no difference was realized by the addition of the scrim. It was finally decided to use scrim in the first DVT model to check out its potential as an abrasion barrier.

2.1.2.4 Liner

Two candidate liner materials were successfully flame tested. These included; (1) a 1.1 oz/yd^2 fire resistant neoprene coated nylon ripstop, and (2) a 7.5 oz/yd^2 fire resistant neoprene coated nylon ripstop. It was agreed that the 1.1 oz/yd^2 fabric needs a 5.2 oz/yd^2 coating of neoprene rather than the minimal amount applied. It was further agreed that one arm and the opposite leg of DVT-001 should be made of the lightweight liner while the opposite arm and leg be made of the heavier weight liner material for DVT cycling. It was also agreed that the existing 7.5 oz. neoprene coated nylon ripstop (not fireproof) could also suffice for cycling tests since the

cycling results would not be affected by the insignificant physical differences between these materials.

2.1.2.5 Thread

The thread selected for the prototype TMG was the same as that in the Apollo/Skylab TMG. (Nomex thread was used to back up the fragile beta thread.)

2.1.2.6 Edgelock

Kel-F 800 was selected as the most suitable edgelock since it is fireproof, commercially available and was successfully used on the Apollo/Skylab programs. This material was used primarily to lock knots and as a back-up to overedging techniques on the shell fabric where overedging is difficult or impossible. This material was also used to repair small pulls, snags or tears.

2.1.2.7 Velcro

Nomex velcro was chosen for use in the TMG.

2.1.2.8 Slide Fasteners

Nylon-cotton tape zippers with nylon teeth were selected because Nomex zipper tapes were only available with heavy, metal chains. This choice was acceptable from the standpoint of cost as well as availability.

2.1.2.9 Fluorel Rubber

Flight qualified, white fluorel rubber was the material chosen to prevent fire paths around the gas connector. A rubber cuff was designed to be fitted at the connector interface to accomplish this purpose.

2.1.3 Materials Testing

2.1.3.1 Abrasion Tests on TMG Shell Materials

Tabor abrader testing was performed on the candidate TMG shell materials (12.5 and 10.3 oz/yd^2) using a 500 gram load. After 10,000 cycles no broken threads were observed on either sample.

2.1.3.2 Lightweight Liner Physical Testing

Physical properties testing was performed on the NASA supplied sample of lightweight neoprene coated ripstop liner candidate. The weight, tensile strength (breaking load and % elongation) and tear strength testing was performed. Based on this testing, it was recommended that the lightweight neoprene coated nylon ripstop be dropped from further consideration for the liner material due to its low tensile and tear strength.

2.1.3.3 Comparison of Physical Properties

The following Table 1 is a comparison of the physical properties of this liner material with the heavier Skylab configured liner.

2.1.3.4 Tensile strength and modulus tests were conducted on embossed and non-embossed aluminized mylar to compare differences between these samples. The non-embossed mylar film had the greatest tensile strength, 4.4 lb/inch, as compared to 2.9 lb/inch for embossed mylar. The embossed mylar broke with little elongation. Hydrostatic testing of the embossed mylar film also revealed that water leakage occurred at the embossment areas. Because of these results the embossed kapton was not considered as a candidate film.

TABLE I

COMPARISON OF PHYSICAL PROPERTIES

	Light Wt. Neoprene Coated Nylon - Test Results		Apollo/Skylab Neoprene Coated Nylon	
	"A" Direction	"B" Direction	Test Results	Specification Requirements (108-1-11)
Breaking Strength	34.8 lb.	38.3 lb.	Warp - 156 lb. Fill - 151 lb.	Warp - 140 lb. min. Fill - 130 lb. min.
% Elongation	25.8%	23.7%	Warp - 37% Fill - 52%	Warp 25% min. Fill - 35% min.
Tongue Tear	2.4 lb.	2.0 lb.	Warp - 6.85 lbs. Fill - 5.05 lbs.	Warp - 4.0 lb. min. Fill - 3.5 lb. min.

2.1.4 Trouser Fabrication

A pair of trousers was manufactured using the candidate TMG shell material to test for flex and wear resistance and to establish cleaning requirements.

2.1.4.1 Trouser Wear Evaluation

2.1.4.1.1 Exterior Surface

The general condition of the trousers following six (6) weeks of wear and cleaning cycles was excellent. The most severe exterior wear areas were identifiable primarily through discoloration of the fabric by repeated contact with work benches, tooling, and the floor, specifically a band over the front of the trousers, and the bottom edge of the cuffs. There was no evidence of yarn damage in these areas with the exception of the bottom edge of the cuff where broken surface yarns were noted, but not in sufficent number to cause fraying or significant loss of strength. Out of approximately a dozen exposed yarn ends throughout the garment, only two appeared to be snags incurred in wear. The rest were minor flaws in the fabric. The two were single yarn snags of no significance. On close examination, the seat of the trousers could be seen to be slightly fuzzier than minimum wear areas, but not to any significant extent.

2.1.4.1.2 Interior Seam Margins

The only wear evident on the interior of the trousers was varying degrees of fraying of the seam edges. All seams which were not overedged were frayed. The fraying did not extend to the first stitch line in most areas, and where it did, it stopped at the seam line. The overedged seams were in excellent condition, even

in those areas adjacent to the most severly frayed non-overedged seams.

2.1.4.1.3 Seam Integrity

All seams in the trousers were intact with no evidence of pulling. Based on this and the effective termination of fraying by a stitch line, the seam holding properties of the fabric would appear to be excellent.

2.1.4.1.4 Shape

The trousers retained their shape with a minimum of bagginess in the knees, and no evidence of deformation of the pocket openings or waist band.

2.1.4.2 Trouser Cleaning Evaluation

The trousers manufactured for the wear evaluation were cleaned after two weeks of wear at the ILC-Dover facility. They were most noticeably dirty in the waistband, pocket openings, and cuffs. In addition, the trousers were spotted with material believed to be dried rubber latex. There were no apparent tears, snags or seam damage in the trousers at the time of cleaning. Raw edged seams, where present, showed moderate fraying. The most effective cleaning agent was found to be a mixture of equal parts of Isopropyl Alcohol and water. Alcohol and Freon were also tried, but the solvents penetrated the material very rapidly, thoroughly wetting underlayers, and not permitting time to remove soil from the surface. There was evidence of transferring soil into the underlayers as opposed to removing it. After some experimentation, a rapid sequence of wet wiping followed by dry wiping of overlapping areas of approximately

one-half square foot were used to cover the entire garment. The process was repeated in areas of heavy soil until visibly clean. Common soil appeared to have been effectively removed, but most of the spots of substance, i.e., adhesives, latex, etc. were unaffected. No further attempt was made to remove these.

2.1.5 Cross Section Selection

Combinations of various candidate TMG cross sections were examined to determine those cross sections which should be used in the flammability testing. These cross sections were evaluated and rated for weight, cost, ease of manufacturing, thermal protection, flammability and cycle life. TMG cross section tradeoff matrices (Appendix C) were used in determining the candidates for the flammability testing.

A description of the cross section samples is as follows:

1. Shell - 12 oz. (1)Ortho-blend.
   Insulation - 1 layer of 17 gram Nomex scrim,
   4 plies of reinforced aluminized mylar.
   Liner - 7.5 oz. fire resistant neoprene coated nylon.
   PGA - 5.25 oz. Kevlar
   10 Mil Perflex E Urethane

2. Shell - 12 oz. (1)Ortho-blend
   Insulation - 4 plies of reinforced aluminized mylar.
   Liner - 7.5 oz. fire resistant neoprene coated nylon
   PGA - 5.25 oz. Kevlar
   10 Mil Perflex E Urethane

3. Shell - 12 oz. (1)Ortho-blend
   Insulation - 1 layer of Nomex scrim
   1 layer of unreinforced perforated Kapton film
   1 layer of Nomex scrim
   3 layers of reinforced aluminized mylar.
   Liner - 7.5 oz. fire resistant neoprene coated nylon
   PGA - 5.25 oz. Kevlar
   10 Mil Perflex E Urethane

4. Shell - 12 oz. (1) Ortho-blend
Insulation - 1 layer of Nomex scrim
4 layers of reinforced Kapton film
Liner - 7.5 oz. fire resistant neoprene coated nylon
PGA - 5.25 oz. Kevlar
10 Mil Perflex E Urethane

5. Shell, Insulation - Identidal to Item #1
Liner - (2) lightweight neoprene coated nylon
PGA - 5.25 oz. Kevlar
10 Mil Perflex E Urethane

6. Shell, Insulation - Identical to Item #2
Liner, PGA - Identical to Item #5

7. Shell, Insulation - Identical to Item #3
Liner, PGA - Identical to Item #5

8. Shell, Insulation - Identical to Item #4
Liner, PGA - Identical to Item #5

9. Identical to Skylab ITMG - baseline
Shell - Teflon coated Beta
Insulation - 1 layer of Kapton
1 layer of Beta marquisette
1 layer of Kapton
1 layer of Beta marquisette
1 layer of Kapton
Liner - Neoprene coated ripstop nylon

10. Shell, Insulation - Identical to Item #9
Liner - Neoprene coated ripstop nylon
PGA 5.25 oz. Kevlar
10 Mil Perflex E Urethane

Note: (1) Blend of Gortex Teflon and Nomex
(2) 3 oz. Fire Resistant Neoprene coated nylon E3251-96-1

2.1.6 Cross Section Testing

The cross section samples were submitted for flammability testing to the NASA Materials Technology Branch ES5. Their detailed report was transmitted by NASA Memorandum ES5-157-75. The testing resulted in the following conclusions:

a. All the lay-ups tested were acceptable for use in the Shuttle crew cabin environment based on self-extinguishing criteria.

b. Lay-ups number 1, 3 and 8 (reference paragraph 2.1.5) were markedly superior to all other lay-ups including the Skylab baseline (lay-up #9) in degree of protection from flame impingement in the Shuttle crew cabin environment.

c. The Perflex "E" Urethane liner has an approximated 16 percent higher thermal degradation temperature than the neoprene coated nylon.

d. None of the lay-ups tested performed significantly worse than the Skylab baseline, layup #9, in the flame impingement testing.

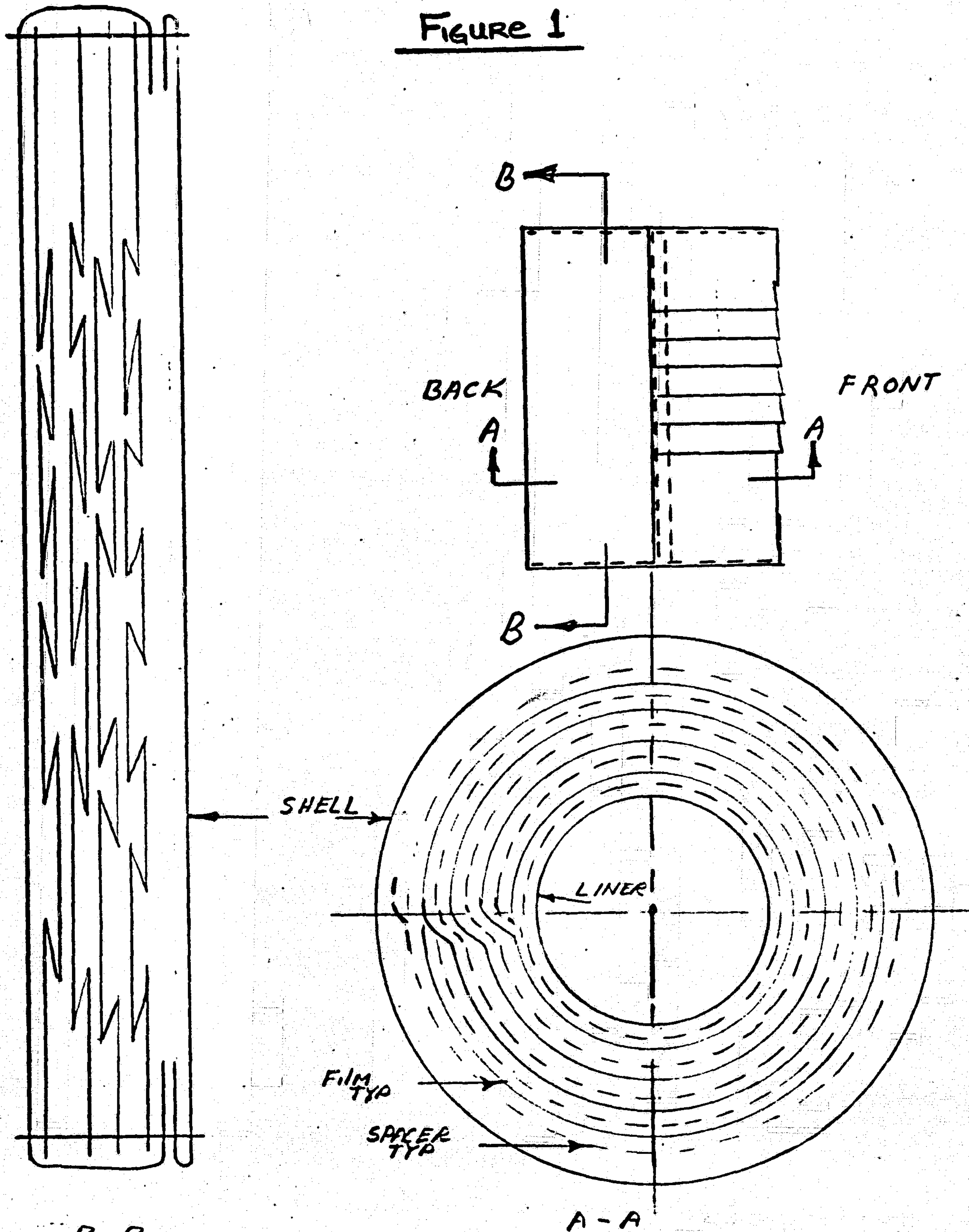
2.1.7 Wrapped Insulation Techniques

A wrapped insulation construction technique was developed. This cylindrical type construction was created by wrapping the pleated insulation around a mandrel to obtain the number of plys required. The insulation is held in place by mylar tape. This method is fast and simple, therefore, cutting manufacturing time and cost.

2.1.7.1 Knee Joint Fabrication

A sample TMG knee joint was fabricated using the wrapped technique and shipped to NASA for evaluation. An illustration of this uniquely constructed knee joint is shown on following page. (Figure 1)

FIGURE 1



B-B
FILM & SPACER SHOWN AS SINGLE LAYER. NOTE RANDOM PLEATS IN AREA OF MOBILITY ONLY BUT COMPLETELY AROUND JOINT.

A - A
SPACING BETWEEN LAYER EXPANDED FOR CLARITY. SEAMS NOT SHOWN

R. Wire
9/9/74

INEXPENSIVE, LIGHTWEIGHT
TME, EXPERIMENTAL
ASSEMBLY TECHNIQUE

2.1.7.2 Knee Joint Testing

The knee testing was actually done twice. The first time the insulation was wrapped as designed but an overlap at the knee area opened during cycling. The remainder of the construction remained intact and showed no visible signs of wear after 100,000 cycles at one cycle per second through 110 degrees of flexing. The second test was run after the overlap was eliminated from the design. The same shell and liner layers were used for the second test. After 100,000 cycles at one cycle per second through 110 degrees of flexing, no visible signs of wear or damage were noted.

2.1.8 Single Layer Pattern Mock-Up

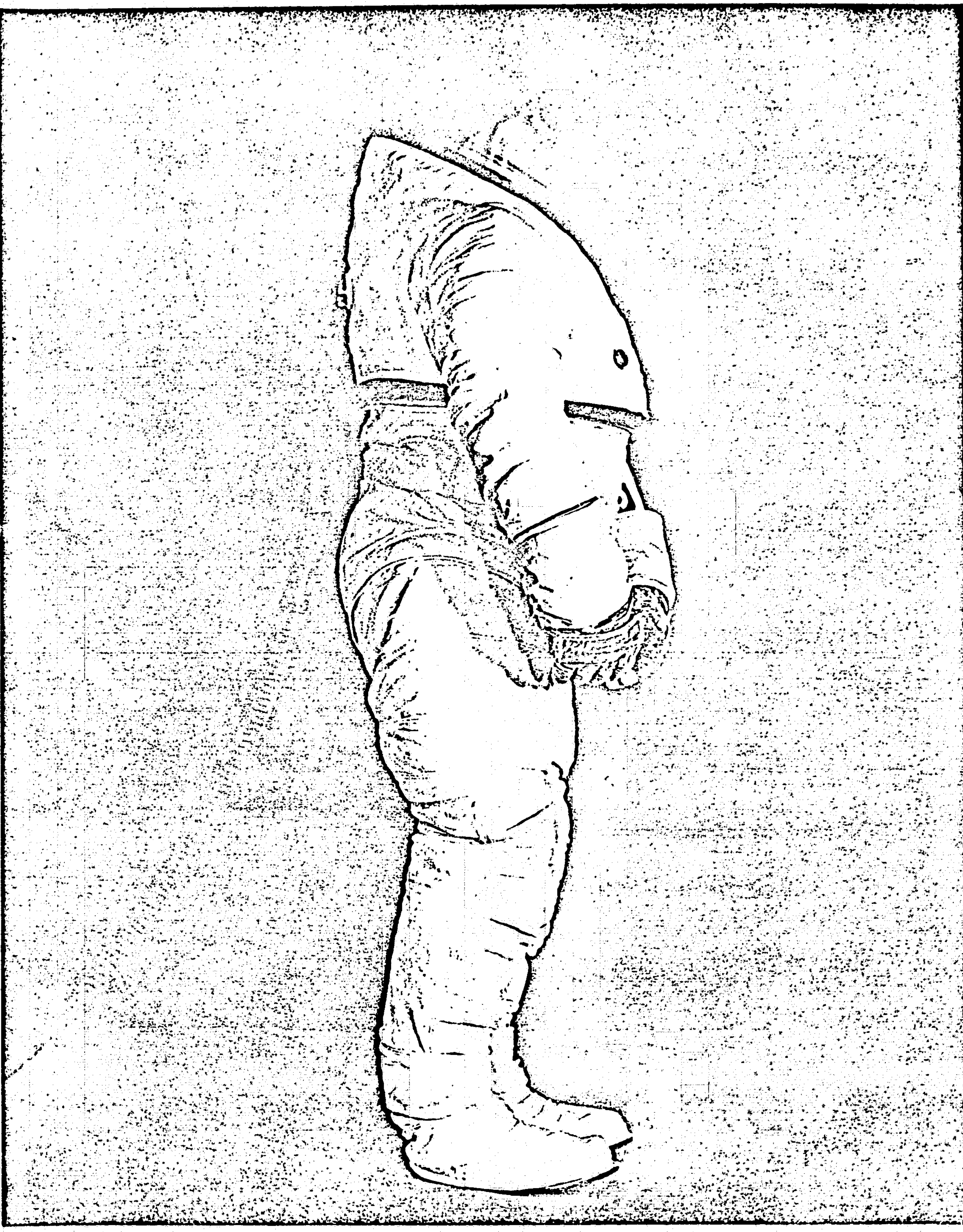
A single layer (liner) mock-up was fabricated using Skylab configured neoprene coated nylon ripstop during the finalizing of the TMG liner patterns. The TMG to suit attachments were also added.

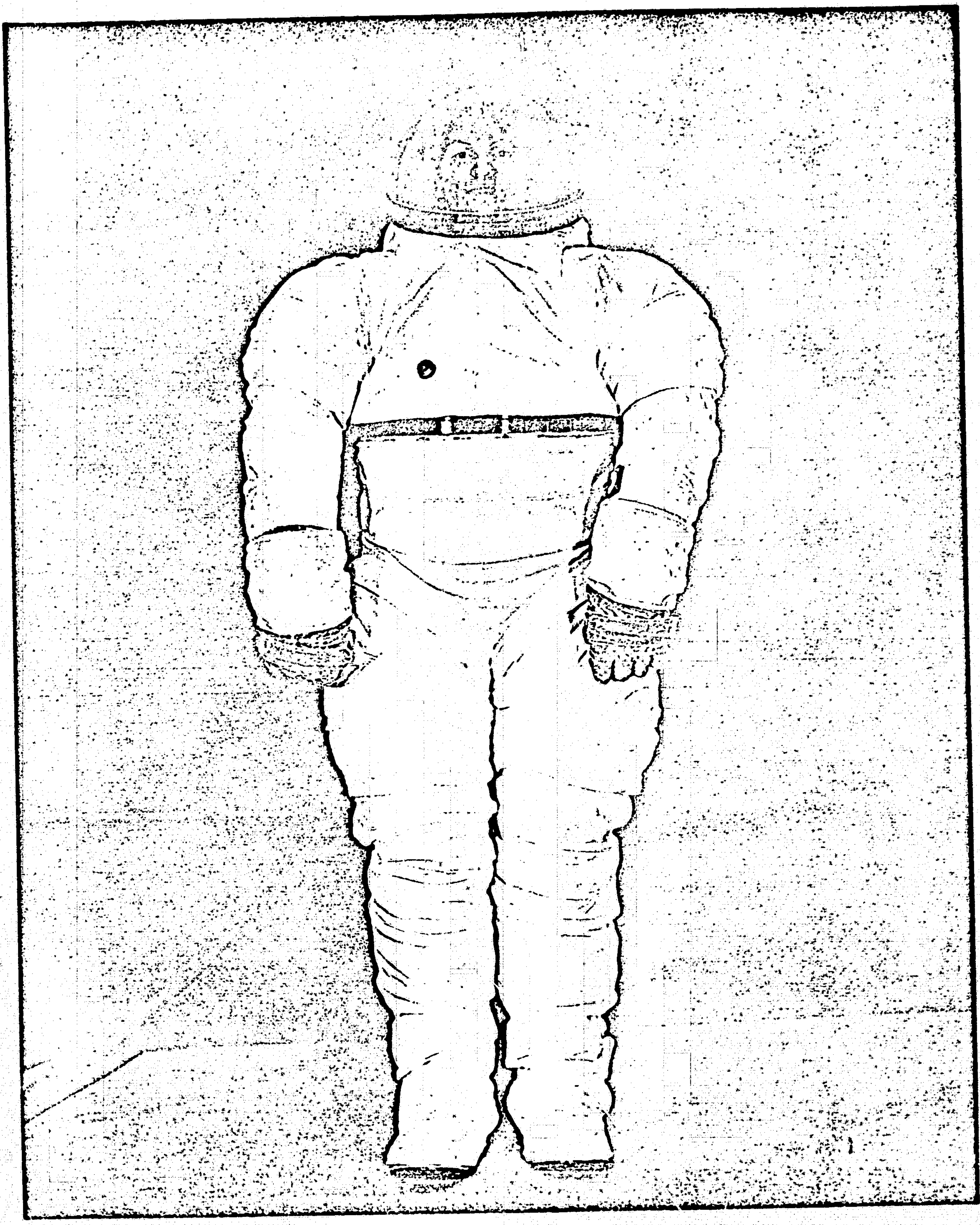
2.2 PHASE II

This phase was directed toward the detailed design of the coverlayer with emphasis on seam construction, TMG to TLSA attachments and patterns.

2.3 PHASE III

Phase III consisted of fabrication of the first prototype TMG (DVT 001). It was completed on 14 January 1975 and delivered to NASA and installed on the OES TLSA for design verification testing. Details of this testing are covered in subsequent paragraphs. A second prototype TMG (DVT 002) was fabricated including changes to eliminate the problems uncovered during cycle testing of DVT 001. A Table of Operations was written for DVT 002 and are part of this report, Appendix D.





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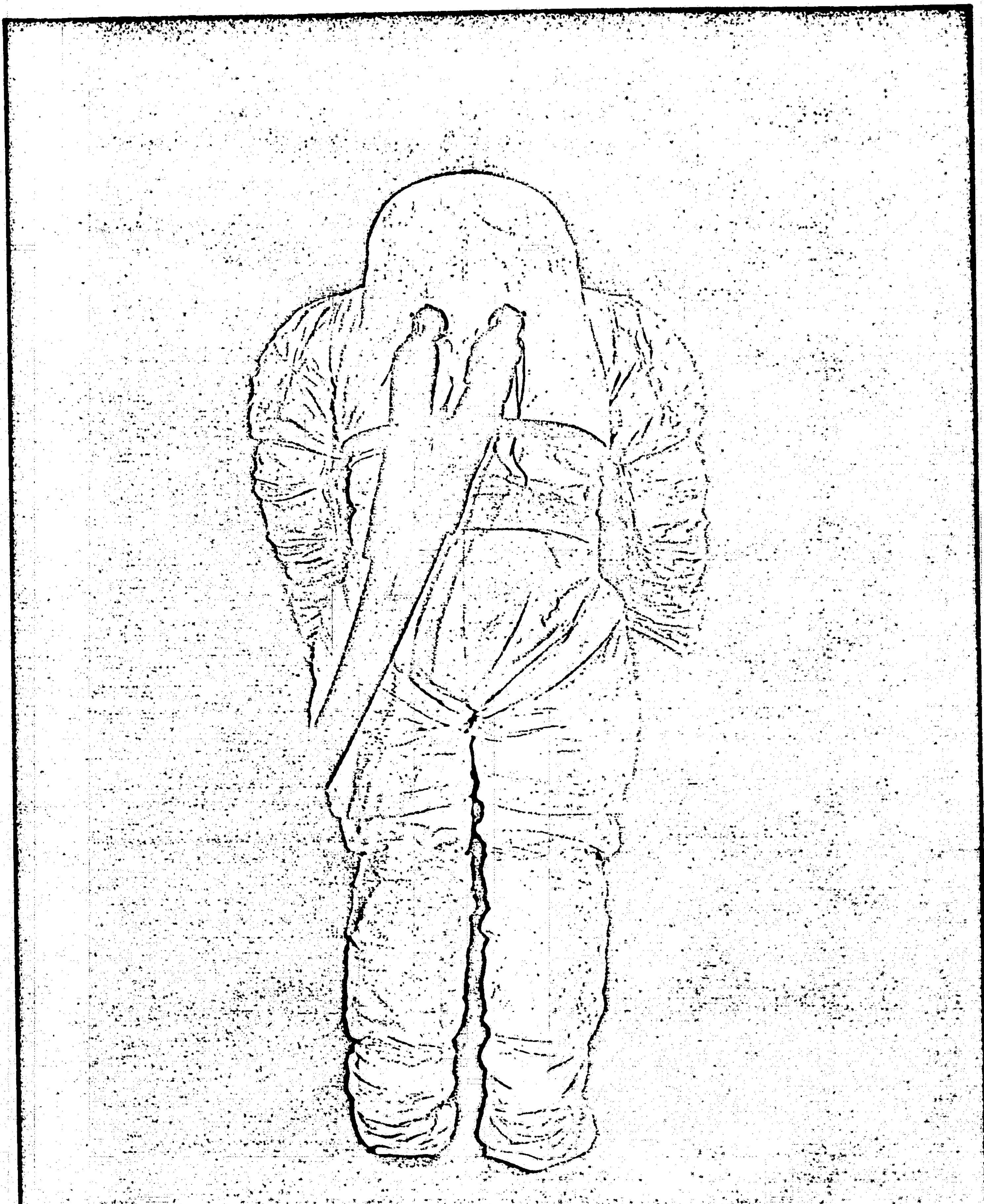

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2.3.1 Fabrication of TMG DVT 001

See the following photographs of the completed TMG DVT-001.

2.3.2 TMG Materials

A goal of this program was to radically reduce the materials costs. This goal was realized and a cost per yard comparison is shown in Tables II and III.

TABLE II

COST OF MATERIALS COMPARISON

OES-TMG, DVT-001 Cross Section

Gortex - Nomex Orthofabric	\$30.00/square yard
Reinforced Aluminized Mylar 4 layers at \$1.00/yd^2	\$ 4.00/square yard
One layer of Nomex scrim at \$1.00/yd^2	\$ 1.00/square yard
Neoprene Coated Nylon Ripstop Liner	\$ 4.00/square yard
Total	\$39.00/square yard

TABLE III

COST OF MATERIALS COMPARISON

Skylab Cross Section

Teflon Fabric	$ 27.25/square yard
Super Beta Fabric	$ 17.00/square yard
Kapton Film - 4 layers	$ 76.60/square yard
Beta Marquisette - 3 layers at $2.50/yd^2 including beta cloth "throw-away" backing	$ 7.50/square yard
Neoprene Coated Nylon Ripstop Liner	$ 4.00/square yard
Total	$132.35/square yard

2.3.3 TMG Labor

Since the object of this effort was to produce a lightweight, inexpensive TMG a manhours record was kept during the fabrication of this garment. This record indicates that 167.4 hours were charged to fabricate the DVT-001 TMG. This compares with approximately 1100 hours for the Apollo TMG and 900 hours for the Skylab TMG.

2.3.4 Weight

During fabrication each TMG section was weighed and these weights are reported in Table IV below. The design goal for the weight was 3632 grams (8.0 lbs) with a not-to-exceed weight of 6356 grams (14.0 lbs). The total weight as shown below was 4540 grams (10.0 lbs) and an interpolation of the weight if the entire garment were made with lightweight liner fabric would be 4358.4 grams (9.6 lbs).

TABLE IV

DVT-001 TMG WEIGHTS

Section	Type of Liner	Weight, Grams
Torso	heavy	602
Brief	heavy	848
Shoulders	left-light; right-heavy	left-272; right 285
Arms	left-light; right-heavy	left-174; right-185
Hips	left-light; right-heavy	left-420; right-428
Legs	left-light; right-heavy	left-658; right-686

2.3.5 TMG Removal/Installation Time

The time to remove and install the TMG liner mock-up to the OES suit was recorded to obtain an estimate of the time that would be required to install the TMG. The removal time was recorded as four minutes and installation time at ten minutes. These times only reflect the use of the TMG liner layer, and it is expected they will increase slightly when performed with the entire TMG cross section.

2.3.6 Estimated Cost in Production

A rough order of magnitude cost in production using existing rates and estimated hours for fabrication, inspection and material costs would be $3,000.00 each.

2.3.7 Test Readiness Review

A Test Readiness Review was held and the prototype was approved for Design Verification Testing. The following are some stastitics of DVT-001.

2.3.8 DVT

During the period January 6 to March 11, 1975 the TMG, installed on the OES, underwent manned and unmanned cycling through an equivalent 50 missions. A copy of the DVT Test Plan used is shown in Appendix E. The test was conducted to provide information as to the design suitability of the Thermal Micrometeroid Garment (TMG). Cycle

testing was conducted on all joints of the suit. Where left and right joints exist, the quantity of cycles performed were applied to both right and left joints. At the completion of testing the TMG appeared by visual examination to be in excellent condition with little or no signs of wear. An internal examination was performed and is explained in detail in the proceeding paragraphs.

2.3.9 Post DVT Examination

The object of DVT cycling was to answer several important questions relating to the TMG design. Some of the more important questions are as follows:

1. What are the comfort and mobility characteristics related to the TMG?
2. What are the wear and tear characteristics of the reinforced mylar film?
3. What is the effect of the stitching at the edge of the mylar films?
4. How does cycling affect the shell and liner layers of the TMG?
5. Does the "wrap around" concept function as expected?
6. Is it necessary to use an abrasion layer of scrim material between the shell and the films?

All of the above questions were answered either during the DVT or during dismantling. Mobility was somewhat impaired by a tight interface at the scye opening, but other mobility was equal to a non-encumbered OES with the exception of a slightly increased weight. Also the OES was as comfortable with the TMG in place as it was without the TMG in place. The film layers, although worn, still appeared to be adequate thermal reflectors. A few tears were discovered in the lower arm section but they would not have caused a

measurable heat leak. There were no problems as a result of film sew-through techniques. The shell layer had not changed significantly as a result of the cycling; and the liner layers, both heavy weight and light weight, were totally intact and showed no signs of damage or wear.

Two problems were discovered during the dismantling that required resolution before fabrication of the second prototype. The first problem is that the beta thread broke in many places throughout the garment. The second problem was that the film layers gapped where they were overlapped and not taped.

In conclusion, the design of the OES TMG appears to be more than adequate. It is recommended as a result of this inspection that the light weight liner be used, the scrim layer be eliminated and that the beta thread be replaced by an acceptable substitute. Detailed changes to the second prototype are listed in the conclusion of this report.

2.3.9.1 Detailed Dismantling Notes

The dismantling was conducted in such a way that the TMG could be reassembled after inspection. This was accomplished by cutting the stitches, carefully removing the thread and cutting the mylar tape as necessary.

The right leg, left hip, brief, torso, left shoulder, and left lower arm were completely dismantled and inspected. The shell was removed from the left leg for verification of bilateral equality. The right hip and right lower arm were left intact.

2.3.9.2 Right Leg Details

The insulation in the leg, although undamaged, was open at the interface between the boot insulation and the leg insulation. The film was unrolled and examined by light transmission. Small specks of total film removal could be seen, and areas of film wear were also evident. There were no tears in the film layer, however, some of the leno reinforcement had been slightly delaminated from the film. The boot ply-up insulation was examined in the same manner and found to be virtually unchanged as a result of the cycling.

2.3.9.3 Left Hip Details

The left hip had a heavy weight liner and a scrim covering. The same general results were evident in the hip as in the right leg. It seems that the scrim layer has little, if any, affect on the wear of the film. Discrepant stitching of the film to the liner (12-16 stitches per inch, rather than 6-8 stitches per inch) resulted in film tearing at the stitch line on one end of the hip. These tears, however, would not have caused any heat leak since they did not propagate more than 1/8-1/4 inch from the stitch line.

2.3.9.4 Brief Details

Examination of the brief revealed that the overlap was gapped in a manner similar to the condition in the legs. The shell, insulation and liner were in similar condition to the leg and hip sections.

2.3.9.5 Torso Details

Examination of the torso indicated no significant wear. The addition of the scrim layer over the film seemed to have little or no effect on the film.

2.3.9.6 Left Shoulder Details

The left shoulder was fabricated using light weight liner fabric. Since the shoulder section was subjected to more radical cycling than other sections, the liner layer was very carefully examined for damage. No damage was evident. The film and the shell were the same as other sections examined.

2.3.9.7 The film wear on the lower arm section was more significant than with other sections. There were small tears through two layers in the elbow area, and the leno weave had broken loose in several areas.

2.3.9.8 Left Leg

The shell layer was removed from the left leg, and a gap identical with that of the right leg was found.

2.3.9.9 Microscopic Examination of Particles

After film examination, a dust covering was noticed on all of the liner layers. The most dust was evident on the hip section, so it was selected for microscopic examination. Under 40 power magnification, the dust appeared crystalline. The opinion of this writer after this cursory examination is that the dust is cement from the leno to film interface. Because of the extremely small amount of this material, and because it is virtually trapped within the garment, the dust will probably not be a problem.

2.3.9.10 Conclusions

Post DVT inspection reveals that the cycling did not significantly damage the Thermal Micrometeroid Garment. The general conclusion, therefore, must be that the design is adequate for this mission. Several specific conclusions can also be drawn from this inspection:

1. The scrim layer is unnecessary.
2. The light weight liner is adequate.
3. The Beta thread should be replaced.
4. Some pattern modifications are necessary.
5. The reinforcement on the mylar is necessary.
6. Stitch count should be carefully controlled.

2.3.9.11 Recommendations That Were Incorporated Into DVT-002

1. Change fire proof thread from Beta to Teflon.
2. Use light weight liner fabric.
3. Eliminate scrim from ply-up.
4. Sew through hip assembly to eliminate roll down.
5. Tape insulation overlaps to prevent gapping.
6. Modify leg insulation pattern to eliminate gapping.
7. Change torso shoulder flap to eliminate excess torque at scye opening.
8. Lengthen brief flap to cover hip section sew-through.
9. Modify shoulder patterns to eliminate shoulder section shortening.
10. Change brief pattern at disconnect interface to eliminate roll down.

2.3.10 Fabrication of TMG DVT-002

TMG DVT-002 was fabricated and completed on 24 March 1975 and delivered to NASA. The recommendations and resolutions determined after completion of cycle testing and dismantling of DVT-001 were incorporated in DVT-002. A copy of TMG DVT-002 fabrication instructions (Table of Operations) is part of this report. (See Appendix D)

2.3.10.1 DVT-002 By Assemblies

	Pounds	Grams
Shoulder (Upper Arms) L/R	1.27	576.58
Lower Arms L/R	.83	376.82
Torso	1.29	585.66
Brief	1.85	839.9
Hip & Thigh (Upper Leg) L/R	1.97	894.38
Leg & Boot L/R	2.94	1334.76
TOTAL	10.15	4608.10

2.3.10.2 Fabrication Time of DVT-002 By Manhours

	Manhours
Layout, Mark & Cut	17
Pleating & Wrapping	8
Leg Assemblies	24
Brief	16
Hip Assemblies	13
Torso Assembly	17
Shoulder Assemblies	12
Lower Arm Assemblies	9
TOTAL	116

During the Apollo/Skylab Program R & D manhours were often multiplied four to six times in production because of controls, inspection and other miscellaneous procedures. Using this conservative factor, this garment may be expected to take no more than 580 manhours to fabricate in fully controlled conditions.

2.3.10.3 Sewn Thru Seams on Final Design

A. Leg Assy - Boot area at heel and toes.

B. Brief Assy - Vertical center front seam, three vertical seams in rear and crotch seam.

C. Hip Assy - Circumferential seam at hip bearing.

D. Torso Assy - Seam joining arm flap to torso.

E. Shoulder Assy - None

F. Lower Arm Assy - None

APPENDIX A

INDUSTRY & LITERATURE SURVEY TELECONS

INDUSTRY & LITERATURE SURVEY

CONTENTS

1.0 "Examination of Space Suit S/N 067 Cover Layer Materials and Mechanical Components"

NASA JSC

Summary:

This report discussed tests conducted on S/N 067 TMG to determine the particle size range and distribution of lunar dust as a function of layer depth. In addition, a visual inspection was also made to determine if any damage has occurred to the TMG after completion of the Apollo 12 lunar mission (Alan Bean).

Only summarized data relative to the damaged areas were utilized since the lunar dust results should not apply to Space Shuttle thermal garments.

Results of Examination:

Figure 10 in this report shows the torn condition of the super Kapton (first insulation layer) of the left kneecap. Figure 12 is a photograph of the torn condition of the second layer of super Kapton in the same location. This report was used to illustrate actual damage which occurred to the insulation layers during use.

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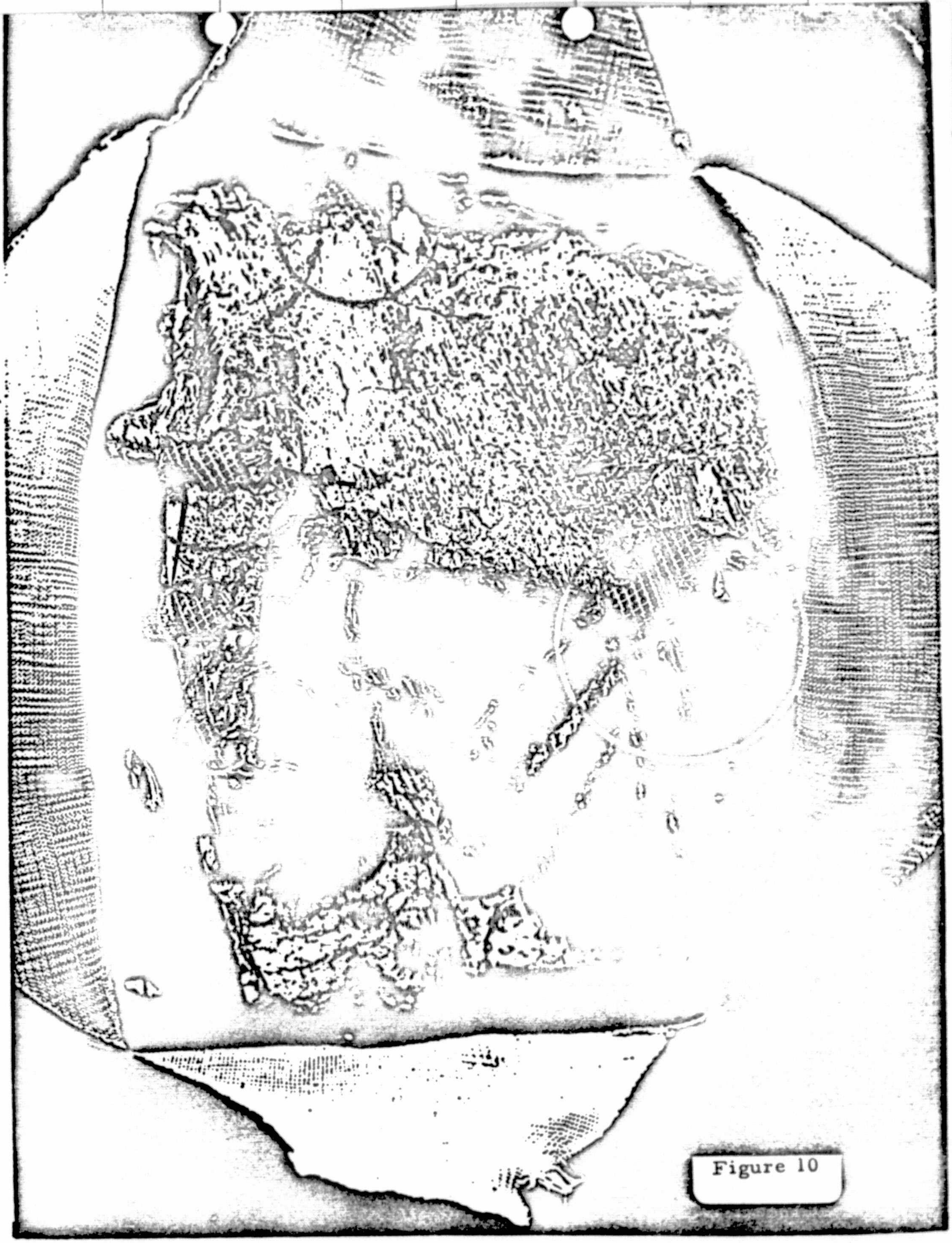

Figure 10

Figure 12

1.0 "Examination of Space Suit S/N 067 Cover Layer Materials and Mechanical Components"

NASA JSC

<u>Major Conclusions:</u>

- The super Kapton radiation shield in the left kneecap of S/N 067 (Apollo 12 - A. Bean) suit was torn with delamination of the aluminum in numerous areas.

2.0 "Post Flight Analysis Report Apollo 12 EMU Integrated Thermal Micrometeoroid Garment Disassembly"

CSD-A-1046

Summary:

Objective:

To provide information on degradation of materials after an actual mission exposure.

Procedure:

After photography of the outer layer, all coverlayer-to-liner seams were opened and the coverlayer removed. Each layer was removed separately, with photos taken before and after removal.

Results:

The Apollo 12 crew had no comments indicating any thermal problem even though some layers of the TMG were damaged. The major material property faults were (a) the super Kapton (Schjedahl 993), delamination and flaking, and (b) the perforated mylars partial loss of its aluminum coating. The fabrication faults were mainly apparent in the fourth (from the outside) layer of perforated mylar. Stress failure in the armpit of both arms was more pronounced in this layer, while present to some degree in all layers. No micrometeoroid penetrations were found during visual examination.

Conclusions and Recommendations;

It is recommended that appropriate action be taken to eliminate the causes of stress failure found in layers four and five and to eliminate the tape bleed through from the dacron layers. Also, it is recommended that additional development be done to obtain a replacement for the fragile super Kapton layers, and

to prevent the aluminum loss from the mylar layers. It is also recommended that the cause and thermal effect of aluminum loss be investigated.

2.0 "Post Flight Analysis Report Apollo 12 EMU Integrated Thermal Micrometeoroid Garment Disassembly"

NASA CSD

<u>Major Results and Conclusions:</u>

- Major delamination and flaking occurred on the super Kapton.
- Stress failures of the radiation shields occurred under each arm of the suit.
- No micrometeoroid penetrations were found during the visual examination.

3.0 "Development of an Improved Extravehicular Space Suit Thermal Insulation"

Arthur D. Little, Inc.

Summary:

A. ABRASION RESISTANCE

a. Recommended the use of 500 Å of vapor deposited germanium on the aluminized Kapton surfaces of the radiation shield. Abrasion tests were run for 1,000 cycles to determine the wear between germanium coated Kapton (duPont) and fiberglass (Beta Marquisette) spacers. The results were good compared to uncoated Kapton.

b. Also recommended the use of applying gold to the Kapton film by a commercial liquid bright gold process. This also produced good abrasion resistance after 500 cycles (low cycling) against fiberglass (Beta Marquisette) spacers at nine successively increasing loads from 0.2 to 1.8 PSI. However, germanium and liquid bright gold coated 0.5 Mil Kapton radiation shield range from self-extinguishing to flammable in air.

B. EVALUATION OF RADIATION SHIELD AND SPACER COMBINATIONS

a. Thermal conductance at no-load

All samples with double aluminized or double gold coated radiation shields and loose spacers of flexible polyurethane foam, Beta Marquisette fiberglass, or multiple plain-weave fiberglass have conductances of 0.0012 to 0.003 BTU/sq. ft. hr °F for the boundary temperature of 70 to -250° F and thermal conductances in the range of 0.0044 to 0.0082 BTU/sq. ft. hr °F for boundary temperatures of 300 - 70° F.

b. Thermal Conductance at 1.0 PSI Compression

Samples with 0.030 inch thick flexible open cell polyurethane foam spacers or samples with Beta Marquisette spacer laminated to the radiation shield and one additional loose Beta Marquisette spacer have conductances in the range of 0.06 - 0.08 BTU/sq. ft hr. °F for 70 to -250° F and the thermal conductance in the range of 0.16 - 0.21 for the boundary temperatures 300° to 70° F.

Samples with a single loose Beta Marquisette spacer, three loose plain fiberglass spacers, or single Beta Marquisette spacers laminated to the radiation shield have conductances in the ragne of 0.08 - 0.10 BTU/sq. ft. hr ° F. for 70 to 250° F and conductances of 0.20 to 0.30 BTU/sq. ft. hr. °F for temperatures of 300° F to 70° F.

C. THERMAL MICROMETEOROID GARMENT ANALYSIS

Recommendations:

I. Multi-layer insulations be used which have:

a. Radiation shields of 0.5 Mil polyimide film with 500 to 800 Å of vapor deposited aluminum and an overcoating of 500 Å of vapor deposited germanium on both sides; or

b. Radiation shields of 0.5 Mil polyimide film with 1000 Å of gold applied to both sides by a liquid bright gold process.

c. Shield spacers made from single layers of beta fiberglass yarn in an open leno-weave similar to the marquisette materials -- J. P. Stevens Style 2530 with 9362 finish; or

d. Shield spacers made from three layers of commercial fiberglass yarns in plain weave (similar to style 104) with 5 to 8% of non-flammable yarn stabilization (3M Fluorel) to prevent unraveling.

II. Manufacturing and Design Recommendations:

a. Insulation layers should not be load bearing and should hang loosely on the pressure retaining layers of the space suit.

b. Radiation shields should stop just short of the edge seam and the shield spacers should be anchored in the edge seam by firm tight stitches. The external layers should be carried around the end of the insulation for flame protection in the event of fire. The seam stitches should be made with double threads, one of Nomex and one of beta fiberglass.

c. The inner layer of the garment is load bearing.

d. The spacer layers are firmly anchored in the seams and penetrations, and the radiation shields terminate no closer than 0.5 inch to seams or penetrations.

e. Tight stitches are never made through the radiation shield layers.

3.0 "Development of an Improved Extravehicular Space Suit Thermal Insulation"

Arthur D. Little, Inc.

Major Conclusions:

- The use of a 500 Å of vapor deposited germanium or 1000 Å of gold (liquid bright gold process) on the radiation shields (0.5 Mil DuPont Kapton) will provide good abrasion resistance during cycling.

4.0 "Multi-layer Insulations Performance in Space Suit Systems"
LTV Aerospace

Summary:

Correlations of average insulation conductance were established based on published test data of element layups and complete space suit assemblies. The results are presented as a function of the number of insulation layers. Local compression of insulation increases the heat transfer and can produce hot spots. The local conductance for a typical externally applied load is presented as a function of the number of insulation layers.

Based on the above data, temperatures inside a manned space suit were determined (again as a function of the number of layers). Three external surface temperatures, +295° F, +200° F and -200° F were evaluated, each with the following conditions:

- Man touching inside wall, compressed insulation
- Man not touching inside wall, compressed insulation
- Man not touching inside wall, uncompressed insulation

An LCG was not considered in this report, since it strongly modifies local temperatures, alievating hot spots. Therefore, areas where the LCG is present do not represent limiting design conditions. All analysis were conducted for those areas where the man is not protected by the LCG.

Results:

• Man in contact with the inside wall, with compressed insulation.	Ultimate limit on pain (113° F), most extreme skin temperatures, conditions exist for very short time periods.
• Man not in contact with the inside wall with compressed insulation.	Conditions less severe than above but exist for much longer time.
• Man not in contact with the inside wall, uncompressed insulation.	Nominal conditions.

No LCG in the local area of interest was considered since it is not a limiting condition.

Each of the above conditions was evaluated with three external temperatures; +295° F, +200° F and -200° F. The temperature of the blood was assumed to be +100° F with hot environments and 97.2° F with cold (an LCG is present providing overall thermal balance for the man). Data were determined as a function of the number of insulation layers and are presented below.

No Contact With Wall, Uncompressed Insulation

Figure 9 presents the inside temperatures for the three external temperatures. The man's skin temperature in this case is always within the limits of pain, 60° F to 113° F, for all temperatures. The inside suit temperature can exceed the threshold of pain under these conditions, since the man is not touching the inside. Even if man does touch the wall @ 113° F, the man will not experience pain (due to the heat capacity of his skin, heat transfer to his blood, and the small heat capacity of the PGA).

This condition can continue for extended periods of time. For the long periods the external suit temperature will

average between +200° F max., and -200° F min. A reasonable degree of comfort should be maintained. If 113° F is taken as the limiting temperature on the wall (102° F skin temperature), then two or three insulation layers is sufficient. Obviously, other criteria can be established with different results.

No Contact, Compressed Insulation

This condition results from an external force applied to the insulation. If this force is not applied by the man, he can still assume this condition by movement inside the suit.

The skin temperatures are always within limits of pain, even with no insulation layers and all temperatures. The inside of the suit greatly exceeds 113° F. However, the man is not in contact and does not experience pain. The man may come in intermittent contact with the hot inside walls but has the freedom to break contact.

Contact With Inside Wall, Compressed Insulation

In this condition the man's skin temperature equals the inside wall. The cold case is never limiting, with any number of insulation layers.

At +200° F external surface temperature one or more insulation layers are sufficient to maintain the skin less than the threshold of pain. At 295° F six or seven insulation layers are necessary. However, as previously noted, a lesser number of insulation layers is sufficient if contact can be broken (either inside the suit or relaxtion of the external compressive load).

The man can control his skin temperature by his actions. The required number of insulation layers is thus a matter of judgment. At one extreme one can provide a very minimum amount of insulation; however, the man may not be able to work effectively in a hot environment. At the other extreme, one can provide a large amount of insulation; while the man can work effectively, a high weight penalty will be incurred.

Considering the above factors, and the general comfort requirements discussed in this report, two or three layers would be a good choice for an EVA suit.

INSULATION SYSTEM WEIGHTS

The PGA has not been included but the following items have:

- Outer Cover : 2 layers of Beta Cloth @ 6.2 oz/yd^2 each
- Ripstop Liner : Bladder Cloth or Blue Oxford Nylon @ 7.5 to 8.0 oz/yd^2

Two types of multi-layer insulation were considered:

1/2 Mil Kapton @	0.8 oz/yd^2
+ Beta Marquisette @	1.8 oz.yd^2
TOTAL	2.6 oz/yd/layer

and

1/4 Mil Mylar @	0.3 oz/yd^2
+ Dacron Scrim @	0.5 oz/yd^2
TOTAL	0.8 oz/yd/layer

The thermal conductance of the two are effectively equivalent.

4.0 "Multi-Layer Insulations Performance in Space Suit Systems"

LTV Aerospace

Major Conclusions:

- Two or three layers of insulation would be a good choice for the Space Shuttle EVA suit.
- The thermal conductance of 1/4 Mil Mylar with a Dacron scrim spacer and 1/2 Mil Kapton with a Beta Marquisette spacer are effectively equivalent.
- The cold case (-200° F) is never limiting with any number of insulation layers.
- The hot case (+295° F) is the limiting design case when the man contacts the inside wall of the suit and the thermal insulation is compressed outside. However, the number of insulation layers required is a matter of judgment since the man can control his skin temperature by his actions, i.e., break contact with the hot spot either inside the suit or by relaxing the external compressive load on the TMG.

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FURTHER ACTION
☐ REQUIRED ☐ NOT REQUIRED

DATE OF CALL	TIME	SUBJECT
6/11/74	10:35 A.M.	SHUTTLE TMG CONTRACT

COMPANY: Arthur D. Little, Inc.

PHONE NO.: 617-864-5770

EXT.:

ADDRESS: Cambridge, Massachusetts

CALL WAS INITIATED

BY J. D'Andrade OF ILC Dover

TO Mr. David Richardson OF Arthur D. Little, Inc.

The purpose of the telecon was to locate the manufacturer of "liquid bright gold" coating discussed in Arthur D. Little report for NASA Contract NAS 9-7519. The following was discussed:

1. "Liquid Bright Gold" is manufactured by Englehart Industries of Newark, New Jersey. It requires baking at approximately 400° F. Samples were made for Arthur D. Little by a gasket manufacturer in Connecticut.

2. We discussed the present ILC TMG contract, and Mr. Richardson made the following recommendations:

   a. We forget about the Germanium and bright liquid gold coatings since they are extremely expensive and probably not provide enough abrasion protection for 100,000 cycles.

   b. Suggested we get double aluminized nylon reinforced mylar from our friends Sheldahl. Use an outer fire protective layer to fire proof the inner mylar layers.

   c. If that's not acceptable (fire protection), he suggested we use nylon reinforced Kapton film instead. However, he believes no film will hold up after the 100,000 cycles.

If you require additional information, please do not hesitate to contact us.

Very truly yours,

ILC INDUSTRIES, INC.

James D'Andrade

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d. Mr. Richardson stated that the sew-through technique we are looking at will produce a sizable heat leak, and he feels the only way to make a lightweight TMG work thermally is to use the same manufacturing techniques we've used in the past to eliminate thermal ~~shock~~ conductance through the seams.

e. Richardson indicated that Arthur D. Little is presently under an "open ended" contract with NASA JSC to perform thermal insulation tests on spacesuit TMG's and evaluate thermal insulation samples through testing. The contract number is NAS 9-11238. Maybe a word to NASA to have them assist us in the initial material selection wouldn't be a bad idea.

JD:dmr

CC: J. McMullen
R. Wise

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DATE OF CALL	TIME	SUBJECT
6/14/74	9:00 A. M.	Shuttle TMG Contract

COMPANY: Arthur D. Little, Inc.

PHONE NO.: (617) 864-5770

ADDRESS: Cambridge, Massachusetts

EXT.:

CALL WAS INITIATED

BY J. D'Andrade OF ILC

TO Mr. David Richardson OF A. D. Little, Inc.

1. The use of a sew-through seam technique was discussed with Mr. Richardson. He agreed with our thoughts that the first TMG prototype should be completely made with sew-through seams and thermally tested at NASA JSC to determine the thermal impact on a suited man. If the results were unacceptable, the second unit should use the Apollo/Skylab sewing technique, which we know will work.

2. Richardson stated that once you laminate a spacer to a shield, you lose one side of that radiation shield. He also stated that it doesn't matter which side of the shield is laminated. Either side will affect both the hot and cold cases. He agreed that this was the bett way to increase the cycle life of the Kaptan but he didn't have any conclusions on the impact thermally of laminated spacers in lieu of loose spacers, except that laminated spacers are worse thermally.

JD/psb

If you require additional information, please do not hesitate to contact us.

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DATE OF CALL	TIME	SUBJECT	
6/14/74	12:00 Noon	TMG DEVELOPMENT - 856	

COMPANY: LTV Aerospace — PHONE NO.: 214-749-6111

ADDRESS: Grande Prairie, Texas — EXT.: 7896

CALL WAS INITIATED

BY J. D'Andrade OF ILC Dover

TO Mr. Bob Copeland OF LTV

The following topics were discussed:

A. The effects of using sew-through seams in lieu of Apollo/ Skylab non-shorting seams.

B. The use of a laminated spacer in lieu of a loose spacer between the aluminized film.

Topic A

Per Bob the use of sew-through seams in the TMG would act approximately the same as the conductance of locally compressed insulation. This could mean a change in conductance from 0.07 to possibly 0.4 BTU/ft^2 hr. °F. He guessed the seam heat leak would be over a 2" wide path. He stated the shorted condition would be the same as the example of the suited crewman leaning against a 1 1/2" diameter bar discussed in NASA/LTV design information release T213-DIR-06 dated April 25, 1974.

This is the same LTV report we received from Houston last week. He stated that the conclusions reached in the report for the compressed insulation condition would be the same as for a sew-through technique. These were:

"(1) The man has no contact with the inside suit wall and the insulation is compressed . . . the skin temperatures are always within the limits of pain, even with no insulation layers and all temperatures (space Shuttle temperatures +295° F, + 200° F and -200° F)."

If you require additional information, please do not hesitate to contact us.

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"(2) The man has contact with the inside wall of the suit and the insulation is compressed. The cold case is never limiting, with any number of insulation layers. At +200° F external surface temperature one or more insulation layers are sufficient to maintain the skin less than the threshold of pain. At 295° F, six or seven insulation layers are necessary. However, as previously noted, a lesser number of insulation layers is sufficient if contact can be broken (either inside the suit or relaxation of the external compressive load). The man can control his skin temperature by his actions."

This LTV/NASA report recommended two (2) or three (3) layers be used for the Shuttle EVA suit. It was also suggested that we make up test samples and send them to Burl French of NASA JSC for transmittal to Arthur D. Little for thermal testing.

Topic B

Bob stated that at low compression levels laminated spacers are worse than loose spacers. At high compression levels laminated spacers are better than loose spacers.

He further noted that with accuracy of the present heat transfer measuring, you probably won't be able to tell the difference in the system heat leak.

JD:dmr

CC: J. McMullen
R. Wise

J Dundeadle 6/14

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DATE OF CALL	TIME	SUBJECT
6/21/74	11:00 A.M.	TMG DEVELOPMENT - 856

COMPANY	PHONE NO.
LTV Aerospace	214-749-6111
ADDRESS	**EXT.**
Dallas, Texas	7896

CALL WAS INITIATED

BY J. D'Andrade OF ILC Dover

TO Mr. B. Copeland OF LTV

Bob was asked about the validity of the +295° F temperature used in the LTV DIR-T213-DIR-06 and the LTV Shuttle EVA Rescue Study reports. Bob's reply included:

1. The +295° F represents the temperature on the floor of the Shuttle Orbiter cargo bay with the doors open and the cargo bay facing the sun.

2. The LTV conclusion to go with a three layer EVA Shuttle suit was based on the +295° F being at a local point on the suit (whatever portion of the suit contacts the floor of the cargo bay) and that the average suit temperature would be +200° F (not in contact with the floor).

3. He further stated that if NASA could accept a higher heat leak into the suit (greater than 250 BTU/hr) that the +295° F would still not be a problem with a three layer garment (he didn't state what the expected heat leak would be).

4. Copeland stated another method of reducing the +295° F contact temperature would be to change the spacecraft payload bay materials or color. It was agreed the chances were remote that North American or NASA would ever agree to do this.

If you require additional information, please do not hesitate to contact us.

James D'Andrade

Very truly yours,

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OTHER ITEMS DISCUSSED:

Bob Copeland believes a flat sample test of sew-through versus non-sew-through seams can be checked out grossly by calorimeter testing. He suggested that LTV could perform two tests with a sample of the complete TMG and suit layup to obtain a gross idea on whether it would be worthwhile to pursue a sew-through seam technique. I advised him that ILC believed an entire suit and TMG were really required but that we would discuss his suggestion with NASA.

JD:dmr

CC: J. McMullen
R. Wise

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DATE OF CALL	TIME	SUBJECT
7/27/74	11:00 A.M.	TMG DEVELOPMENT - 856

COMPANY: LTV Aerospace

PHONE NO.: 214-749-6111

ADDRESS: Dallas, Texas

EXT.:

CALL WAS INITIATED

BY J. D'Andrade OF ILC

TO Dr. Roy L. Cox OF LTV

The use of silicone monoxide coating on the Shuttle TMG radiation shield was discussed with Roy Cox. Dr. Cox agreed that silicone monoxide will definitely improve the abrasion resistance of the film but that it will raise the emittance. He further stated that the increase in emittance can be controlled by the SiO coating thickness. He suggested ILC contact B. French to determine if anyone has ever run any thermal tests on SiO coated radiation shields.

JD:dmr

CC: J. McMullen
R. Wise

If you require additional information, please do not hesitate to contact us.

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DATE OF CALL	TIME	SUBJECT	
6/21/74	10:00 A.M.	TMG DEVELOPMENT - 856	
COMPANY: Schjeldahl, G. T. Company			PHONE NO.: 507-615-5631
ADDRESS: Northfield, Minnesota			EXT.: 276

CALL WAS INITIATED

BY J. D'Andrade OF ILC Dover

TO Mr. Jerry Maas OF Schjeldahl

The subject ILC Space Shuttle TMG Development Program was discussed with Messrs. Milt Wertema and Jerry Maas. The object of the discussion was to determine if Schjeldahl had any new products available that could replace the super Kapton film used on previous programs. Mr. Maas, head of the materials group, described a new embossed Kapton film which is Kapton embossed with a pattern to produce point contact between the film layers. Mr. Maas claims that this can eliminate the need for spacers between the radiation shields. However, he believes the strength may be reduced due to the embossing process. He stated that North American Rockwell is presently evaluating its use for insulating the Shuttle Orbiter. He agreed to send me a sample of embossed Kapton and embossed Mylar for ILC examination.

Lamination of a non-woven or woven reinforcement for the embossed Kapton was also discussed. He stated they were presently developing a method of bonding non-woven nylon in a triangular pattern for reinforcing the film. The embossed Kapton is the only new film they have available and Mr. Maas estimated the cost to be approximately $.20 more per square foot than the cost of Super Kapton film.

JD:dmr

CC: J. McMullen
R. Wise
G. Alexandroff

If you require additional information, please do not hesitate to contact us.

J. D'Andrade

Very truly yours,

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DATE OF CALL	TIME	SUBJECT	
7/31/74	9:30 A.M.	TMG PROGRAM	

COMPANY	PHONE NO.
G. T. Schjedahl	507-645-5631

ADDRESS	EXT.
Northfield, Minnesota	

CALL WAS INITIATED

BY Mr. Dick Slater OF G. T. Schjedahl

TO J. D'Andrade OF ILC Dover

Mr. Slater, Vice President, Materials Engineering Department, returned my call of 7/30/74. It was requested that Schjedahl send us a sample of 1/4 mil aluminized mylar on a kevlar leno weave and/or 1/2 mil aluminized Kapton on a Kevlar leno weave. It was explained that a small sample of this reinforced film was received from the Fabric Development Company, but they were unable to supply a larger sample for testing purposes.

Mr. Slater stated that the Fabric Development Company supplied Schjedahl with the Kevlar leno weave, and it's possible that none of these reinforced film samples may be available at Schjedahl.

Mr. Slater also pointed out that Schjedahl would like to help assist ILC via telecons in the final selection of the film layers for the Shuttle suit. He advised me to call himself or Jerry Maas (materials marketing) if ILC wanted some changes to present Schjedahl films in order to meet our special requirements. He stated Schjedahl is very interested in special applications such as this one.

Mr. Slater will try to locate some samples of the reinforced film requested and transmit them to ILC today.

JD:dmr

If you require additional information, please do not hesitate to contact us.

Very truly yours,

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DATE OF CALL	TIME	SUBJECT
9/5/74	11:00 A.M.	TMG PROGRAM

COMPANY	PHONE NO.
G. T. Schjedahl	507-645-5631
ADDRESS	EXT.
Northfield, Minnesota	

CALL WAS INITIATED

BY J. D'Andrade OF ILC Dover

TO Mr. Jacobie OF G. T. Schjedahl

Mr. Maas who was working on the requested quotation was on travel and Mr. Henjum was attending a meeting. Mr. Jacobie is responsible for the metallizing at Schjedahl. Mr. Jacobie was familiar with the ILC request and provided the following information:

1. If ILC needs a three foot width of material we should provide Schjedahl with a wider width such as 38".

2. The metallizing of the laminated film is not an easy process, especially over the fabric side of the film. To insure that ILC will get 60 yards of laminated reinforced film, Schjedahl would like 120 yards in case any problems arise.

3. Schjedahl has aluminized a 1/2 mil Kapton on a Nomex Leno weave and aluminized both sides for the Skylab mission. A sample of this is presently with Fred Dawn of NASA. The Leno weave used had smaller 1/8 X 1/16 inch openings versus the 1/4 inch openings we're using.

4. Schjedahl laminates the film on one machine and aluminizes it on a second machine.

5. Cost for aluminizing and laminating 60 yards of 1/2 mil Kapton to Nomex Leno is $3,100.00.

6. Schedule if ILC provides the Nomex by September 19 is no later than October 18.

JD:dmr

If you require additional information, please do not hesitate to contact us.

J. D'Andrade

Very truly yours,

ILC INDUSTRIES, INC.

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J. McMullen, R. Wise

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DATE OF CALL	TIME	SUBJECT	
8/21/74	10:10 A.M.	TMG PROGRAM	
COMPANY			PHONE NO.
G. T. Schjedahl			507-645-5631
ADDRESS			EXT.
Northfield, Minnesota			

CALL WAS INITIATED

BY Mr. Harvey Henjum OF G. T. Schjedahl

TO J. D'Andrade OF ILC Dover

Mr. Henjum called to further discuss the details of his telecon of 8/20/74. He noted that ILC should request the Fabric Development Company to make the Kevlar such that it meets the normal Schjedahl size requirements to simplify the set-up operations. He suggested that ILC have Fabric Development Inc. call Schjedahl to discuss this matter. In addition, he pointed out that some of Schjedahl's non-flammable adhesives are not presently NASA Space qualified and asked what the complete program requirements were.

Finally Mr. Henjum quoted a price of $200-$300 per run of mylar to Kevlar Leno (schedule, labor day week) or Kapton to Kevlar Leno. This would be a maximum of $600 if a four yard sample of each film is needed. I advised Mr. Henjum the price would probably break our budget, but that we would contact him between today and Friday and give him an answer.

JD:dmr

CC: R. Wise
J. McMullen

JDAndrade

If you require additional information, please do not hesitate to contact us.

Very truly yours,

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DATE OF CALL	TIME	SUBJECT
6/24/74	9:15 A.M.	TMG Development - 856

COMPANY	PHONE NO.
Exxon Chemical Company	713-221-0416

ADDRESS	EXT.
Houston, Texas	

CALL WAS INITIATED

BY Mr. J. D'Andrade OF ILC Dover

TO Mr. Jack Thorn OF Exxon

This telecon was initiated to determine if a new Exxon film known as "Polyparbonic Acid Polymer" could be used as a radiation shield for the subject program. Mr. Jack Thorn, manager of new ventures for the plastics department stated the following:

1. Exxon has not started marketing this material commercially to date. They are presently trying to find a market requiring millions of pounds of the material.

2. It is presently being produced in 2, 3 and 5 Mil thicknesses and it probably won't be very strong if manufactured in thickness of less than one mil.

3. This material is presently being used for flexible printed circuit boards and flexible cables.

4. The polyparbonic acid polymer is self-extinguishing in air but not as good as Kapton.

5. Kapton is good to approximately 700-800° F while the Exxon material is good to 500° F.

6. The cost of polyparbonic acid polymer is $12-$15 per pound.

J D'Andrade

If you require additional information, please do not hesitate to contact us.

Very truly yours,

ILC INDUSTRIES, INC.

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7. Mr. Thorn stated that we should stick with the Kapton polyimide film we've been using since he believes its superior to the Exxon product for our application. He also stated that with our small volume, Exxon probably won't be interested in our business.

JD:dmr

CC: J. McMullen
R. Wise
G. Alexandroff

ILC INDUSTRIES, INC.

CONFIRMATION OF TELCON

FOR ILC USE ONLY
FURTHER ACTION
☐ REQUIRED ☐ NOT REQUIRED

DATE OF CALL	TIME	SUBJECT
7/30/74	4:00 P.M.	TMG PROGRAM

COMPANY: NASA-JSC PHONE NO.: 713-483-4961

ADDRESS: Houston, Texas EXT.:

CALL WAS INITIATED

BY J. D'Andrade OF ILC Dover

TO Mr. B. French OF NASA

Mr. Burl French of NASA was contacted concerning the use of a silicone oxide (siO_2) coating on an aluminized Kapton film. Mr. French stated that he and A. D. Little "really thought they had something" when they first received a sample of this material. However, testing at A. D. Little demonstrated this coating had bad long wave length properties and will heat up the film causing a subsequent conductance problem. As a result, this coating was dropped from consideration even though it had excellent abrasion resistant properties.

Mr. French stated that the Bright Liquid Gold process proved to be extremely expensive and that germanium coating was the best. However, the germanium coated Kapton was difficult to find , and A. D. Little presently holds the patent rights for the germanium coating process.

Mr. French also pointed out that he is familiar with the General Dynamics "Super Flock" film and that it would no doubt work in a static condition. It was questionable in his mind, however, if it would work in a suit where the film would be exposed to movement causing thermal shorting between the film layers.

JD:dmr

CC: J. McMullen
R. Wise

J. D'Andrade

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DATE OF CALL	TIME	SUBJECT
9/6/74	9:15 A.M.	TMG PROGRAM

COMPANY: National Metalizing

PHONE NO.: 609-655-4000

ADDRESS: New Jersey

EXT.:

CALL WAS INITIATED BY Mr. Dick ~~Hagerdawn~~ Hagadorn OF National Metalizing

TO J. D'Andrade OF ILC Dover

Mr. ~~Hagerdawn~~ Hagadorn returned my call to provide a cost estimate for 60 linear yards of 1/2 mil Kapton on a 1/2 oz. Nomex Leno, 200 denier, 36 inches wide: cost, $2,153.00.

He will require about 75 yards of material to make 60 yards.

The cost increase is due to the need to use about three pounds of Kapton at $517/lb. In addition, they will not aluminize over the Nomex Leno fabric.

Schedule: Approximately 1 1/2 weeks after receipt of fabric if we give them about 1 1/2 weeks notice.

JD:dmr

CC: J. McMullen
R. Wise

J. D'Andrade

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DATE OF CALL	TIME	SUBJECT
6/21/74	11:40 A.M.	TMG DEVELOPMENT - 856

COMPANY: Rockwell International

PHONE NO.: 213-923-1951

ADDRESS: Downey, California

EXT.:

CALL WAS INITIATED

BY Mr. Don Martin OF North American

TO J. D'Andrade OF ILC Dover

Mr. Martin called regarding my previous telecon on 6/20/74 requesting the expected wall temperatures for the Shuttle Orbiter payload bay with the doors open and facing the sun. Mr. Martin works for O. T. Stole, Manager of the Environmental Requirements Group. Mr. Martin's reply was that the present expected contact temperatures are 250° F to 280° F along the side walls and floor but that this temperature would probably increase if NAR goes to a new insulation material presently under review. He suggested we design the suit and TMG to meet 310° F as a goal. This obviously disagrees with our present TMG contract which calls for 200° F maximum and a Skylab layup.

JD:dmr

CC: J. McMullen
R. Wise

J. D'Andrade

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APPENDIX B

SPECIAL FABRICS CONSIDERED

PRECEDING PAGE BLANK NOT FILMED

A. SHELL LAYER:

ILC recommended that the shell layer be a special blend and that Nomex II be dropped from consideration. It was explained that Nomex II was not as fire resistant as previously believed, is relatively unavailable and has poor abrasion resistance. As a result, it should not be considered for the shell of this garment. The blend recommendations centered on a fabric with a weight of 10 oz/sq. yard, a breaking strength of 180 lb/inch, a tear strength of 20 lb/inch, abrasion resistance better than 7 oz. Nylon, a flex life of 100,000 cycles, and it should be non-burnable or self-extinguishing. It was suggested that this fabric be a weave blend of Teflon, Kevlar and Beta fibers in a double cloth, a triple cloth or a French back. Mr. Naimer, of NASA, disliked the term blend and suggested that we use the terminology ortho-fabrics. ILC agreed. NASA also suggested that ILC seriously consider the use of a more flame resistant Nomex called Durette by Monsanto (Monsanto Research Corporation, 1515 Nicholas Road, Dayton, Ohio, F. Winslow and R. Cass). Mr. Naimer also disclosed that a worse case atmosphere relative to flammability had been specified for Shuttle. This atmosphere definition is 31% oxygen, 69% nitrogen at 10 PSIA. After considerable discussion, it was decided to purchase ortho-fabrics as follows:

1. A Teflon outer surface for abrasion with a Kevlar inner surface for strength.

2. A Teflon outer surface for abrasion with a Nomex inner surface for less costly strength (Note: it was decided that the Durette process might be applicable to this blend without affecting the Teflon portion. This would be done if the Nomex alone does not work.)

3. A French back fabric consisting of a Teflon outer surface for abrasion resistance, a Nomex inner surface for strength and Kevlar yarns to tie the two fabrics together.

A special ortho-fabric was woven by Fabric Development, Inc. This fabric will be woven with 400 denier Gortex (an expanded teflon) 2 ply, 200 denier nomex, and 400 denier Kevlar. The object of this specialized weave is to produce a fabric with a white teflon (Gortex) exterior, a nomex interior and a ripstop of Kevlar. During the initial stages of the weaving, short run samples of several candidate weaves will be manufactured for evaluation by ILC and NASA JSC. Selected candidates from these samples will then be manufactured for sample fabrication and further evaluation.

Eight samples of ortho-fabrics for evaluation of use on the TMG shell were transmitted to NASA JSC for examination. Table I illustrates the details of these samples. Also, the decision was made to fabricate three (3) additional TMG shell samples consisting of the following: (Table II)

TABLE I

TMG SHELL
ORTHOWEAVE CANDIDATES
(Obtained from first run samples)

NOTE: Weight is from 4" X 4" samples. Comments from micro examination.

Sample No.	Description	Warp	Fill	Weight oz/sq yd	Comments
1.	Face Tie Back	Gortex 42/inch Gortex 10/inch Nomex/Kevlar 42/inch	Gortex 42/inch Nomex/Kevlar 42/inch	8.93	Gortex too light. Could use 20% more count. Nomex/Kevl[illegible] good.
2.	Face Tie Back	Gortex 42/inch Gortex 10/inch Nomex/Kevlar 42/inch	Gortex 84/inch Nomex/Kevlar 42/inch	10.87	Effect of extra fill thread is negated due to twist.
3.	Face Tie Back	Gortex 42/inch Gortex 10/inch Nomex/Kevlar 42/inch	Gortex 84/inch Nomex/Kevlar 42/inch plus Gortex 42/inch	12.44	Extra Gortex in back adds weight. No benefits noted.
4.	Face Tie Back	Gortex 42/inch Gortex 10/inch Nomex/Kevlar 42/inch	Gortex 42/inch Kevlar 42/inch Nomex/Kevlar 42/inch Gortex 42/inch	13.75	Kevlar fills gap better than Gortex did. Twist is evident in this sample.
5.	Face Tie Back	Gortex 42/inch Nomex/Kevlar 10/inch Nomex/Kevlar 42/inch	Gortex 42/inch Nomex/Kevlar 42/inch	9.86	Fabric looks better with this tie system.
6.	Face Tie Back	Gortex 42/inch Nomex/Kevlar 10/inch Nomex/Kevlar 42/inch	Gortex 84/inch Nomex/Kevlar 42/inch	11.17	No bumps on front as in sample No. 2.

Sample No.	Description	Warp	Fill	Weight oz/sq yd	Comments
7.	Face Tie Back	Gortex 42/inch Nomex/Kevlar 10/inch Nomex/Kevlar 42/inch	Gortex 84/inch Nomex/Kevlar 42/inch plus Gortex 42/inch	13.49	Same as #3 without bumps but heavier.
8.	Face Tie Back	Gortex 42/inch Nomex/Kevlar 10/inch Nomex/Kevlar 42/inch	Gortex 42/inch Kevlar 42/inch Nomex/Kevlar 42/inch Gortex 42/inch	13.90	Same as #4 without bumps but heavier.

No.	Description	Warp	Fill
1.	Face	Gortex 50/inch	Gortex 50/inch
	Tie	Gortex 10/inch	
	Back	Nomex/Kevlar 40/inch	Nomex/Kevlar 40/inch
2.	Face	Gortex 50/inch	Gortex 50/inch
	Tie	Nomex/Kevlar 10/inch	
	Back	Nomex/Kevlar 40/inch	Nomex/Kevlar 40/inch
3.	Face	Gortex 50/inch	Gortex 100/inch
	Tie	Nomex/Kevlar 10/inch	
	Back	Nomex/Kevlar 40/inch	Nomex/Kevlar 40/inch

TABLE II

B. FILM LAYER:

The following are the material candidates and special processes considered and conclusions.

1. 0.5 Mil Kapton vs. 0.3 Mil Kapton

   Conclusion: 0.3 Mil Kapton was eliminated due to its decreased strength.

2. Germanium or Bright Gold Coatings

   Conclusion: These processes were dropped due to excessive cost.

3. Inconel Coating

   Conclusion: Dropped due to excessive cost.

4. Exxon's Polyparbonic and Polymer Film

   Conclusion: Dropped due to small quantity required. Exxon is looking for a large market and is not manufacturing this product at this time.

5. Silicone Monoxide (SiO) Coating

   Conclusion: This coating had bad long wave length properties and will heat up the film causing conductive problem, therefore, its use was dropped.

6. General Dynamics "Super Flock" Film

   Conclusion: During dynamic useage, such as in space suit, the radiation film layers would most likely have numerous thermal shorts.

7. Aluminized Kapton Film Reinforced with a Leno Weave Fabric

   Conclusion: Dropped due to cost and schedule considerations.

8. Nomex Leno Reinforced Kapton

   Conclusion: To be tested.

9. Aluminized Kapton on a Nylon Leno

   Conclusion: To be tested.

C. SPACER:

ILC discussed the merits and drawbacks of a Kevlar triaxial Marquisette spacer construction but recommended that a Kevlar Leno and a new nonwoven Nomex be purchased. ILC revealed that Kendal Industries had recently made a substantial improvement in their nonwoven Nomex material. NASA suggested that ILC also consider nonwoven Dacron if a nonflammable liner can be obtained. Three other interesting spacer materials were suggested by NASA. These materials would have to be obtained by NASA and GFE'd to ILC for evaluation. The first of these materials is one being made by General Dynamics, presumably for the Shuttle Orbiter insulation, called Super Flock. The second is a material called CTFE-E (Chlorotetrafluoroethylene/ethylene). This is apparently a nonflammable fiber. The third material is a polyimide fiber called PI-2080.

Although spacer layers may not be required if the laminated films prove acceptable, ILC shall still continue to examine spacer materials. As a result, a 17 gram/sq. yd., non-woven nomex fabric should be delivered to ILC from Kendall Corporation. Kendall is currently manufacturing several thousand yards of 25 gram/sq. yd. material and have agreed to modify the setup slightly to manufacture a small quantity of 17 gram/sq. yd. material.

D. <u>LINER LAYER</u>:

Nylon ripstop coated with fire resistant neoprene coating was the final decision for the liner.

Conclusion: To be tested.

APPENDIX C

TMG CROSS SECTION

TRADE-OFF MATRICES

LIGHTWEIGHT, INEXPENSIVE
TMG CROSS SECTION
TRADE-OFF MATRICES

Combinations of various candidate TMG cross sections were examined to determine those cross sections which should be utilized in flammability testing. Combinations of the following candidate shell, spacer, film, numbers of film layers and liner materials were used in this study with the nomenclature as noted:

Candidates	ID Code	Description
Shells	G	Ortho-fabric shell constructed as follows: Exterior - 200 denier Gortex Warp 50 ppi Fill 100 ppi (cone over cone) Interior - 200 denier Nomex with 200 denier Kevlar 29 as ripstop. Warp 42 ppi with 2 Kevlar every 18 picks. Fill 42 ppi with 2 Kevlar every 18 picks. The fabric is tied Gortex to Nomex.
	g	Same as G except that the exterior fill is 50 ppi rather than 100 ppi (cone over cone).
	N	9 ounce/yd^2 Nomex
Spacers	B	Beta leno weave
	S	Nomex scrim
		No spacer used

Films	K	1/2 Mil aluminized Kapton with spacers.
	M	1/4 Mil aluminized Mylar with spacers.
	K_R	1/2 Mil aluminized Kapton with laminated reinforced nylon.
	M_R	1/4 Mil aluminized Mylar with laminated reinforced nylon.
Film Layers	3	Three (3) layers of film.
	4	Four (4) layers of film.
Liners	R_F	2.3 oz/yd^2 nylon coated with 5.2 oz/yd^2 fire resistant neoprene rubber (Reeves Brothers, Inc.)
	R_L	Lightweight 1.1 oz/yd^2 nylon coated with 5.2 oz/yd^2 fire resistant neoprene rubber (NASA, A. D. Little, E. I. duPont DeNemours).
	R	Standard Skylab TMG Liner - 2.3 oz/yd^2 nylon coated with 5.2 oz/yd^2, non-fire resistant neoprene.

Table I was prepared using the above discussed candidate materials in all possible combinations. Options not considered were:

A. The no spacer cannot exist when plain aluminized Kapton or Mylar are used as the films. A spacer must be used to separate the layers and prevent thermal shorts from occurring between layers.

B. Beta spacer was not considered a candidate with Mylar film.

Table I illustrates all the possible combinations of TMG materials considered. The next step was to evaluate and rate each of these candidate cross sections for weight (Table II), cost (Table III), ease of manufacturing (Table IV), thermal protection (Table V), flammability (Table VI), and cycle life (Table VII). Each of these six categories were rated using the same matrix format and locations used in Table I. Therefore, to determine the rating of a TMG cross section with a large quantity Gortex (G) shell, a Beta spacer (B), four layers of nylon reinforced aluminized Kapton (K_R4), and the heavy weight nylon reinforced fire resistant neoprene liner (R_F), Table I should be inspected to determine the location of this cross section. This is done by identifying the cross section by the location numbers appearing vertically and horizontally outside the matrix. In this case 1, 1 locates the example cross section. These same location numbers are then used in Tables II through VII to determine this cross section rating in each of the six categories studied.

TMG cross sections were examined in order to determine which cross sections should be selected for flammability testing. During this evaluation, the following questions were considered:

1. Which shell materials are acceptable? If Nomex is the candidate, it must be obtained in a quantity sufficient to product the two (2) TMG's.

2. Is Kapton necessary for fire ressitance? In view of its high cost and low tear strength, it should be absolutely necessary before it is used as the film layer.

3. Does the use of fire resistant materials on both sides of Mylar film allow its use as the TMG film?

4. Does a Nomex or Beta spacer under the shell increase the fire resistance? If so, this is an inexpensive way to obtain fire resistance.

5. Does the cement on the reinforced Mylar or reinforced Kapton burn?

Considering these questions, the following cross sections were selected as the candidates for the initial flammability testing. If the situation warrants, further tests can be conducted on other candidates.

A.	8 - 12	Low cost, low weight
B.	1 - 4	Worst case weight and cost - best flammability
C.	1 - 2	Most likely candidate to be acceptable
D.	1 - 3	Test to find out if the scrim helps
E.	2 - 2	Test to check out the fireproof liner theory

COMBINATIONS OF THE MATERIALS
AND QUANTITY OF FILM LAYERS

	1	2	3	4	5	6	7	8	9	10
1	G, B, K_R 4, R_F	G, S, K_R 4, R_F	G, K_R 4, R_F	G, B, K 4, R_F	G, S, K, 4, R_F	G, B, K_R 3, R_F	G, S, K_R 3, R_F	G, K_R 3, R_F	G, B, [illegible] 3, [illegible]	[illegible], S, [illegible] [illegible], [illegible]
2		G, S, M_R 4, R_F	G, M_R 4, R_F		G, S, M, 4, R_F		G, B, M_R 3, R_F	G, M_R 3, R_F		[illegible] 3, [illegible]
3	g, B, K_R 4, R_F	g, S, K_R 4, R_F	g, K_R 4, R_F	g, BK 4, R_F	g, SK 4, R_F	g, BK_R 3, R_F	g, SK_R 3, R_F	g, K_R 3, R_F	g, B[illegible] 3, R_F	g, [illegible] K 3, P
4		g, SM_R 4, [illegible]	g, M_R 4, R_F		g, SM 4, R_F		g, SM_R 3, R_F	g, M_R 3, R_F		g, SM 3, R_F
5	N, B, K_R 4, R_F	N, S, K_R 4, R_F	N, K_R 4, R_F	N, B, K, 4, R_F	N, S, K, 4, R_F	N, B, K_R 3, R_F	N, S, K_R 3, R_F	N, K_R 3, R_F	N, B, K, 3, R_F	N, [illegible], K [illegible], R_F
6		N, S, M_R 4, R_F	N, M_R 4, R_F		N, S, M 4, R_F		N, S, M_R 3, R_F	N, M_R 3, R_F		N, S, M, 3, R_F
7	G, B, K_R 4, R_L	G, S, K_R 4, R_L	G, K_R 4, R_L	G, B, K, 4, R_L	G, S, K, 4, R_L	G, B, K_R 3, R_L	G, S, K_R 3, R_L	G, K_R 3, R_L	G, B, K, 3, R_L	G, [illegible] [illegible], [illegible]
8		G, S, M_R 4, R_L	G, M_R 4, R_L		G, S, M, 4, R_L		G, S, M_R 3, R_L	G, M_R 3, R_L		[illegible], S, M 3, R_L
9	g, B, K_R 4, R_L	g, S, K_R 4, R_L	g, K_R 4, R_L	g, B, K, 4, R_L	g, S, K, 4, R_L	g, B, K_R 3, R_L	g, S, K_R 3, R_L	g, K_R 3, R_L	g, B, K, 3, R_L	g, S, K, 3, R_L
10		g, S, M_R 4, R_L	g, M_R 4, R_L		g, S, M, 4, R_L		g, S, M_R 3, R_L	g, M_R 3, R_L		g, S, M. 3, [illegible]
11	N, B, K_R 4, R_L	N, S, K_R 4, R_L	N, K_R 4, R_L	N, B, K, 4, R_L	N, S, K, 4, R_L	N, B, K_R 3, R_L	N, S, K_R 3, R_L	N, K_R 3, R_L	N, B, K, 3, R_L	N, S, [illegible] 3, R_L
12		N, S, M_R 4, R_L	N, M_R 4, R_L		N, S, M, 4, R_L		N, S, M_R 3, R_L	N, M_R 3, R_L		[illegible], S, M, 3, R_L
13	G, B, K_R 4, R	G, S, K_R 4, R	G, K_R 4, R	G, B, K, 4, R	G, S, K, 4, R	G, B, K_R 3, R	G, S, K_R 3, R	G, K_R 3, R	G, B, [illegible] 3, R	G, S, K, 3, P
14		G, S, M_R 4, R	G, M_R 4, R		G, S, M, 4, R		G, S, M_R 3, R	G, M_R 3, R		G, S, [illegible] 3, [illegible]
15	g, B, K_R 4, R	g, S, K_R 4, R	g, K_R 4, R	g, B, K, 4, R	g, S, K, 4, R	g, B, K_R 3, R	g, S, K_R 3, R	g, K_R 3, R	g, B, K, 3, P	g, S, [illegible] [illegible], [illegible]
16		g, S, M_R 4, R	g, M_R 4, R		g, S, M, 4, R		g, S, M_R 3, R	g, M_R 3, R		g, S, M 3, R
17	N, K 4, R	N, S, K_R 4, R	N, K_R 4, R	N, B, K, 4, R	N, S, K, 4, R	N, B, K_R 3, R	N, S, K_R 3, R	N, K_R 3, R	N, B, [illegible] 3,	N [illegible], K 3, R
18		N, S, M_R 4, R	N, M_R 4, R		N, S, M, 4, R		N, S, M_R 3, R	N, M_R 3, R		N, S, M, 1, R

CYCLING DURABILITY

	1	2	3	4	5	6	7	8	9	10
1	2	2	2	7	7	4	4	4	8	8
2	X	1	1	X	5	X	3	3	X	6
3	2	2	2	7	7	4	4	4	8	8
4	X	1	1	X	5	X	3	3	X	6
5	2	2	2	7	7	4	4	4	8	8
6	X	1	1	X	5	X	3	3	X	6
7	2	2	2	7	7	4	4	4	8	8
8	X	1	1	X	5	X	3	3	X	6
9	2	2	2	7	7	4	4	4	8	8
10	X	1	1	X	5	X	3	3	X	6
11	2	2	2	7	7	4	4	4	8	8
12	X	1	1	X	5	X	3	3	X	6
13	2	2	2	7	7	4	4	4	8	8
14	X	1	1	X	5	X	3	3	X	6
15	2	2	2	7	7	4	4	4	8	8
16	X	1	1	X	5	X	3	3	X	6
17	2	2	2	7	7	4	4	4	8	8
18	X	1	1	X	5	X	3	3	X	6

This assumes mylar is better than Kapton and reinforced is better than non-reinforced and four plies is better than three plies.

1 - 4 M_R
2 - 4 K_R
3 - 3 M_R
4 - 3 K_R
5 - 4 M
6 - 3 M
7 - 4 K
8 - 3 K

	1	2	3	4	5	6	7	8	9	10
1	26.88	25.59	24.98	29.94	24.78	25.61	24.32	23.71	27.43	23.56
2		24.27	23.66		23.42		22.43	21.82		22.81
3	24.78	23.49	22.88	27.84	22.68	23.51	22.22	21.61	25.33	21.46
4		22.17	21.56		21.32		20.33	19.72		20.71
5	23.48	22.19	21.58	26.54	21.38	22.21	20.92	20.31	24.03	20.16
6		20.87	20.26		20.02		19.03	18.42		19.[illegible]
7	25.[illegible]	24.39	23.78	28.74	23.58	24.41	23.12	22.51	26.23	22.[illegible]6
8		23.07	22.46		22.22		21.23	20.62		21.61
9	23.58	22.29	21.68	26.64	21.48	22.31	21.02	20.41	24.13	20.2[illegible]
10		20.97	20.36		20.12		19.13	18.52		19.51
11	22.28	20.99	20.38	25.34	20.18	21.01	19.72	19.11	22.83	18.96
12		19.67	19.06		18.82		17.83	17.22		18.21
13	26.88	25.59	24.98	29.94	24.78	2[illegible].61	24.32	23.71	27.43	[illegible].56
14		24.27	23.66		23.42		22.43	21.82		22.8[illegible]
15	24.78	23.49	22.88	27.84	22.68	23.51	22.22	21.61	25.33	21.4[illegible]
16		22.17	21.56		21.32		20.33	19.72		20.71
17	23.48	22.19	21.58	26.54	21.38	22.21	20.92	20.31	24.03	20.16
18		20.87	20.26		20.02		19.03	18.42		19.41

Assumption: With non-reinforced film, the same number of spacers and films are used; i.e., "4 B, K" equals 4 B's and 4 K's.

<u>Unit Weights</u> in oz/yd^2

G 12.40
G 10.30
N 9.0
M_R .94
M .27
K_R 1.27
K .61
B 1.90
S .61
B_F 7.50
R 7.50
R_L 6.30

THERMAL PROTECTION

	1	2	3	4	5	6	7	8	9	1
1	5	5	5	3	2	10	10	10	8	7
2	X	4	4	X	1	X	9	9	X	6
3	5	5	5	3	2	10	10	10	8	7
4	X	4	4	X	1	X	9	9	X	6
5	5	5	5	3	2	10	10	10	8	7
6	X	4	4	X	1	X	9	9	X	6
7	5	5	5	3	2	10	10	10	8	7
8	X	4	4	X	1	X	9	9	X	6
9	5	5	5	3	2	10	10	10	8	7
10	X	4	4	X	1	X	9	9	X	6
11	5	5	5	3	2	10	10	10	8	7
12	X	4	4	X	1	X	9	9	X	6
13	5	5	5	3	2	10	10	10	8	7
14	X	4	4	X	1	X	9	9	X	6
15	5	5	5	3	2	10	10	10	8	7
16	X	4	4	X	1	X	9	9	X	6
17	5	5	5	3	2	10	10	10	8	7
18	X	4	4	X	1	X	9	9	X	6

Thermal protection assumes: four plies better than three
Mylar better than Kapton
Non-reinforced better than reinforced
For non-reinforced Nomex scrim is better than Beta Marquisette
Other factors are ignored

Therefore: 4 MS_1, 4 KS_2, 4 KB_3, 4 MR_4, 4 KR_5, 3 MS_6, 3 KS_7, 3 KB_8, 3 $M_{R\,9}$, 3 $K_{R\,10}$

FIRE RESISTANCE

	1	2	3	4	5	6	7	8	9	10
1	2	4	5	1	3	12	14	15	11	13
2	X	82	83	X	81	X	85	86	X	84
3	22	24	25	21	23	32	34	35	31	33
4	X	94	95	X	93	X	97	98	X	96
5	42	44	45	41	43	52	54	55	51	53
6	X	106	107	X	105	X	109	110	X	108
7	7	9	10	6	8	17	19	20	16	18
8	X	88	89	X	87	X	91	92	X	90
9	27	29	30	26	28	37	39	40	36	38
10	X	100	101	X	99	X	103	104	X	102
11	47	49	50	46	48	57	59	60	56	58
12	X	112	113	X	111	X	115	116	X	114
13	62	64	65	61	63	72	74	75	71	73
14	X	128	129	X	127	X	131	132	X	130
15	67	69	70	66	68	77	79	80	76	78
16	X	134	135	X	133	X	137	138	X	136
17	118	120	121	117	119	123	125	126	122	124
18	X	140	141	X	139	X	143	144	X	142

This very rough estimate is based on the following assumptions:

Shell - G better than g better than [illegible]
Film - K better than K_R, M better [illegible] than M_R
Spacer - B better than S
Layers - 4 better than 3
Liner - M_F better than M_L better than M

- That layers with separate spacers are better than reinforcements.
- That an extra spacer under the shell helps.
- That the fireproof liner renders the mylar layers fireproof.

EASE OF MANUFACTURING

	1	2	3	4	5	6	7	8	9	10
1	10	8	4	1	14	9	6	2	15	[illegible]
2	X	7	3	X	12	X	5	1	X	11
3	10	8	4	16	14	9	6	2	15	13
4	X	7	3	X	12	X	5	1	X	11
5	10	8	4	16	14	[illegible]	6	2	15	13
6	X	7	3	X	12	X	5		X	11
7	[illegible]	8	4	16	14	9	6	2	15	[illegible]
8	X	7	3	X	12	X	5	1	X	11
9	10	8	4	16	14	9	6	2	15	[illegible]
10	X		3	X	12	X	5	1	X	11
11	[illegible]	8	4	16	14	9	6	2	15	[illegible]
12	X	7	3	X	1	X	5	1	X	11
13	10	8	4	16	14	9	6	2	15	13
14	X	7	3	X	12	X	5	1	X	11
15	10	8	4	16	14	9	6	2	15	13
16	X	7	3	X	12	X	5	1	X	11
17	10	8	4	16	14	9	[illegible]	2	15	13
18	X	7	3	X	12	X	5	1	X	11

Assumptions: Three plies easier than four plies
Reinforced easier than non-reinforced
Nomex easier than Beta Marquisette
Mylar easier than Kapton

1	3 M_R	9	3 B, K_R
2	3 K_R	10	4 B, K_R
3	4 M_R	11	3 S, M
4	4 K_R	12	4 S, M
5	3 S, M_R	13	3 S, K
6	3 S, K_R	14	4 S, [illegible]
7	2 S, M_R	15	3 B, K
8	4 S, K_R	16	4 B, K

1	139	138	137	117	113	111	110	109	94	91
2	X	29	28	X	31	X	29	28	X	[illegible]
3	135	134	133	113	109	107	106	105	[illegible]	87
4	X	25	24	X	27	X	25	24	X	
5	134	133	132	112	108	106	105	104	89	86
6	X	24	23	X	26	X	23	22	X	24
7	139	138	137	117	113	111	110	109	94	[illegible]
8	X	29	28	X	31	X	28	27	X	29
9	135	134	133	113	109	107	106	105	90	87
10	X	25	24	X	27	X	24	23	X	25
11	133	132	131	111	107	105	104	103	88	85
12	X	23	22	X	25	X	23	22	X	24
13	139	138	137	117	113	111	110	109	94	91
14	X	29	28	X	31	X	28	27	X	30
15	135	134	133	113	109	107	106	105	90	87
16	X	25	24	X	27	X	24	23	X	26
17	134	133	132	112	108	106	105	104	89	86
18	X	24	23	X	26	X	23	22	X	24

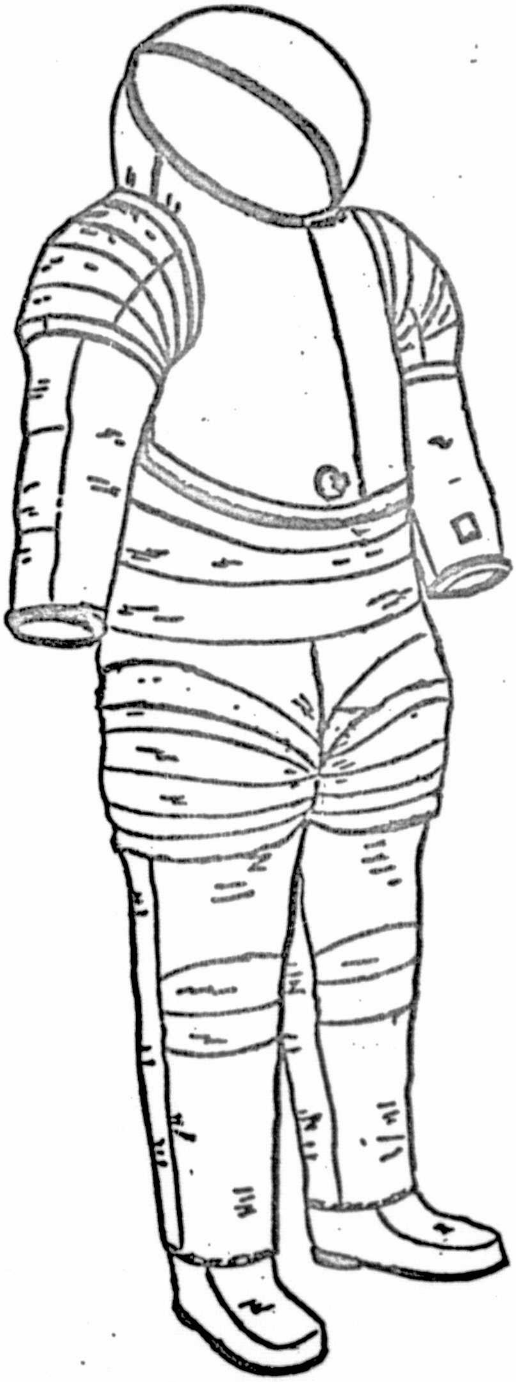
Rough Order of Magnitude (ROM) cost estimates based on:

G = $21.00/yd^2	B = $2.00/yd^2	M = $.50/yd^2	R_F = $4.25/yd^2
G = $17.00/yd^2	S = $1.00/yd^2	K = $21.00/yd^2	R_L = $3.75/yd^2
M = $15.50/yd^2	M_R = $.75/yd^2	K_R = $28.00/yd^2	R = $4.00/yd^2

APPENDIX D

TABLE OF OPERATIONS

DVT-002



FABRICATION INSTRUCTIONS

OES/TMG

DVT 002

TABLE OF CONTENTS

MATERIALS LIST

Nomenclature	Manufacturer	Quantity Required
Shell-Gortex- Nomex Ortho-Fabric	Fabric Development, Inc.	7 yds.
Insulation-Reinforced Aluminized Mylar	National Metalizing	28 yds.
Liner-Neoprene Coated Nylon Ripstop	GFE	7 yds.
Velcro Fastener-Nomex 1" wide	American Velcro	3 yds.
Gas Connector Rings-Fluorel Rubber L-4993-4	Raybestos-Manhattan	
Slide Fastener-Cotton & Nylon Tape/Nylon Zipper Teeth	Talon Corp.	
Boot Toe 12 1/4" Long		2 each
Boot Heel 9 3/4" Long		2 each
Top of Leg 20 3/4" Long		2 each
Hip 32 1/2" Long		2 each
Shoulder 11" Long		4 each
Waist 50" Long		1 each
Neck 28 1/2" Long		1 each
Upper Torso 50" Long		1 each
Lower Arm 15 3/8" Long		2 each
Tape, Aluminized Mylar, Pressure Sensitive 1/2" Wide	ST13M038-01	5 yards
Fluorocarbon Resin (Kel-F-800)	ST41F392-01	AR
Cord, Nylon 1/16" Diameter	ST41N014-03	2 yards
Tape Loop Nylon 3/8" Wide	ST13N227-01	2-1/2 yards
Thread Teflon	ST15T247-01	AR
Thread Nomex	ST15N055-01	AR

PATTERN LIST

Shell Material: Gortex-Nomex Orthofabric

Template Reinforcement Around Front Valve Opening

Template Reinforcement Around Back Valve Opening

Template Reinforcement Pressure Gauge

Elbow Upper Section, Back, Left/Right

Elbow Lower Section, Back, Left/Right

Elbow Middle Section, Back, Left/Right

Knee Section, Front, Left/Right

Lower Leg Cone, Front, Left/Right

Upper Leg Cone, Front, Left/Right

Thigh, Overlap Piece, Left/Right

Lower Leg, Back, Left/Right

Lower Boot, Left/Right

Boot Insert, Left/Right

Ankle, Left/Right

Torso Back-Left

Torso Back-Right

Torso Front-Left

Torso Front-Right

Upper Shelf

Upper Shelf Band

Waist Section Back

Waist Section Front

Hip, Middle Section, Left/Right

Shell (continued)

Hip, Upper Section, Left/Right

Hip, Lower Section, Left/Right

Hip, Flange, Left/Right

Upper Arm Flange, Left/Right

Shoulder, Lower Section, Left/Right

Shoulder, Middle Section, Left/Right

Shoulder, Flange-Torso, Left/Right

Shoulder, Upper Section, Left/Right

Shoulder, Upper Middle Section, Left/Right

Elbow front, Left/Right

Brief, Front and Side, Left/Right

Brief, Back, Left/Right

Brief, Leg Flap

LINER MATERIAL: Neoprene Coated Nylon

Ankle, Left/Right

Insert Boot, Left/Right

Lower Boot, Left/Right

Lower Leg Cone, Front, Left/Right

Knee Section-Front, Left/Right

Upper Leg Cone-Front, Left/Right

Lower Leg Back, Left/Right

Elbow Upper Section, Back, Left/Right

Elbow Middle Section, Back, Left/Right

Elbow Lower Section, Back, Left/Right

Elbow, Front, Left/Right

Thigh Overlap Piece, Left/Right

Shoulder, Upper Middle Section, Left/Right

Shoulder, Middle Section, Left/Right

Shoulder, Lower Section, Left/Right

Upper Arm Flange, Left/Right

Waist Section, Back

Upper Shelf

Waist Section, Front

Hip, Lower Section, Left/Right

Shoulder, Upper Section, Left/Right

Upper Shelf Band

Hip, Upper Section, Left/Right

LINER & INSULATION (PLY-UP)	MATERIAL: Reinforced Aluminized Mylar
Shoulder Flange-Torso, Left/Right	
Torso Back	
Torso Front	
Brief Leg Flap	
Brief, Front and Side, Left/Right	
Breif, Back, Left/Right	

INSULATION	MATERIAL: Reinforced Aluminized Mylar
Lower Boot, Left/Right	(Ply-up)
Elbow	(Wrap Around)
Waist Middle Section	(Wrap Around)
Shoulder	(Wrap Around)
Hip	(Wrap Around)
Elbow	(Wrap Around)
Shoulder Section	(Wrap Around)

TOOLS

Mold, Ring, Gas Connector

GENERAL CHARACTERISTICS

In order to prevent continual repetition, operations performed in the same manner throughout this T/O will be referenced in these General Characteristics and not repeated. Any deviations will be clarified within the operation itself.

<u>TERMINOLOGY:</u> The following terminology will be used to identify the "Face Side" of materials used:

Liner - Cloth side

Insulation - Shiny side of film

Shell - White side

<u>STITCHING:</u>

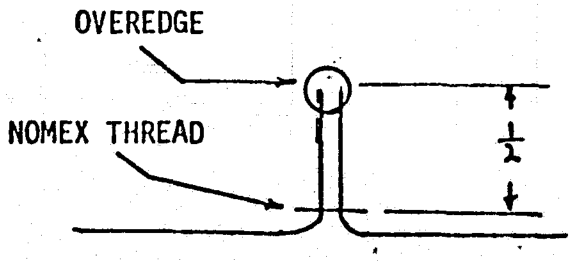
1. All stitching will be six to seven stitches per inch.
2. Thread ends will be tied securely with a double square knot. Thread need not be knotted if crossed by a later seam.
3. Knots will be coated with Binder (Fluorocarbon Resin, Kel-F 800).
4. Thread ends will be trimmed no less than 1/4 inch from knots.

<u>SEAMS:</u>

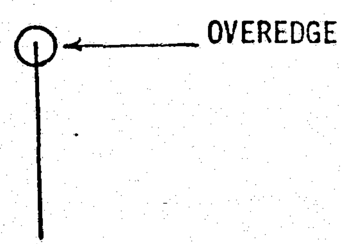
A. <u>Shell</u>

1. All shell pieces are joined face sides together with a 1/2 inch join seam, unless otherwise specified, using Teflon thread.

2. All raw edges of join seams will be overedged together prior to top stitching using Nomex thread. See Figure below:

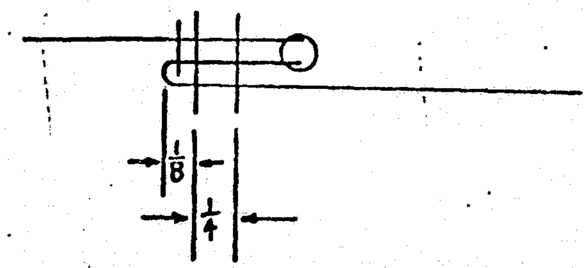


3. All Shell raw edges that are not joined such as Arm, Leg, Neck, Waist, Boot bottoms, openings will be overedged using Nomex Thread.



4. Topstitching of Shell join seams:
   a. The turn of the seam in most cases will be:
      1. Side seams turned to back; 2. horizontal seams turned down.

b. Seams are topstitched with two (2) rows of stitches 1/4 inch apart, 1/8 inch from fold using Nomex thread.



c. The above topstitched seam is typical of joining shell parts.

B. Liner

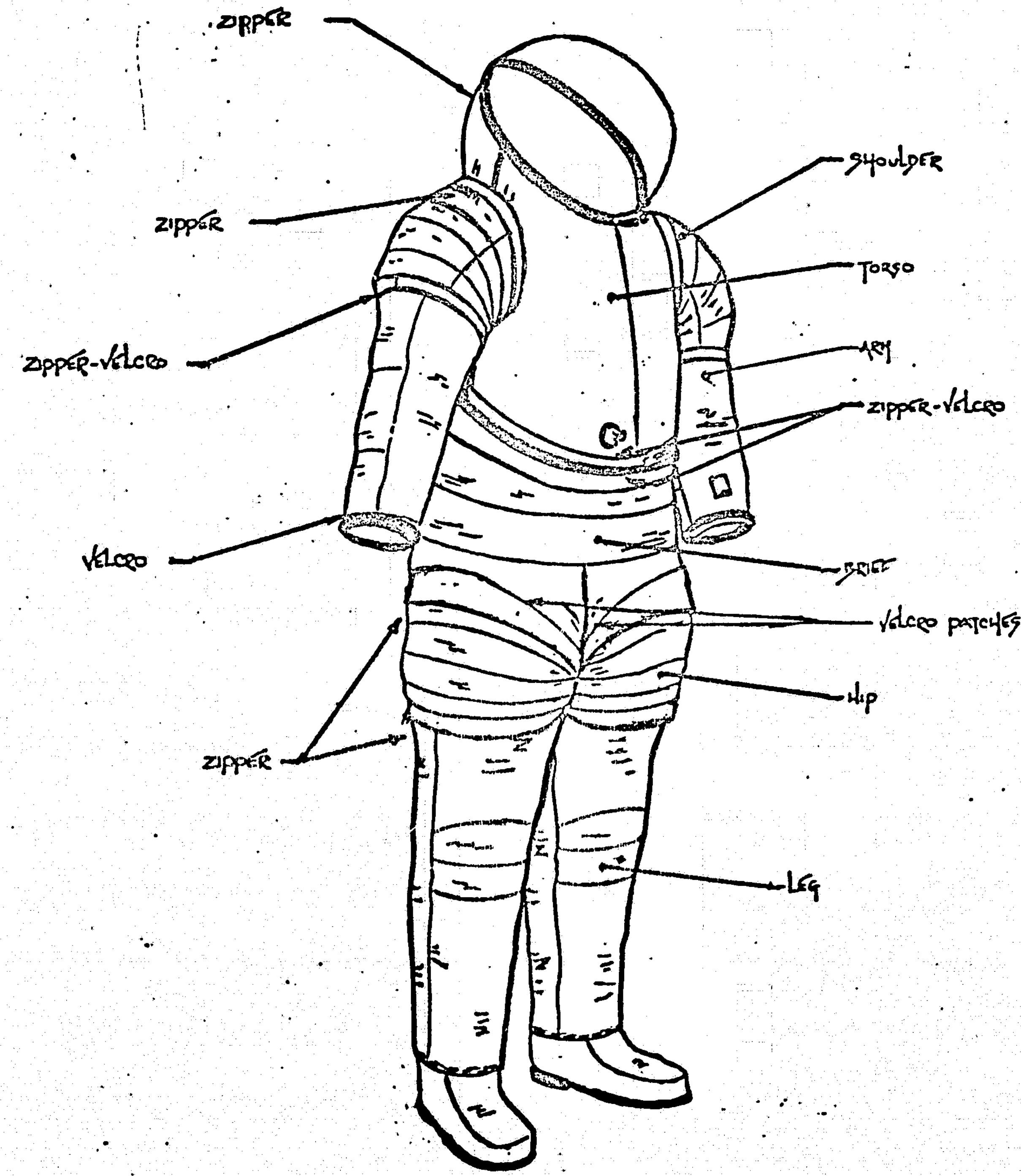
1. All join seams of liner parts are joined rubber sides together, 1/4 inch from raw edge using Nomex thread. Turn seam using same basics as called out for Shell and topstitch with one row of stitches 1/16 inch from fold using Nomex thread. See figure below:

2. Whenever the Liner and a ply-up of insulation are joined, they will not be topstitched.

<u>MIXING OF BINDER</u> - Use 20 grams of Kel-F-800 Resin. Add 100 millileters of Methyl Ethyl Ketone (MEK). Should further dilution be required, an added quantity of MEK, up to equal weight of the solution, is permissible.

NOTE: Methyl Ethyl Ketone (MEK) is an extremely volatile solvent which should be kept covered when not in use.

<u>CURING OF BINDER</u> - The binder, after application, shall be air dried until tack free.


ZIPPER
SHOULDER
ZIPPER
TORSO
ZIPPER-VELCRO
ARM
ZIPPER-VELCRO
VELCRO
BRIEF
VELCRO PATCHES
HIP
ZIPPER
LEG

C-2

OPERATION 1.1 LAY-OUT, MARK AND CUT

1.1.1 Lay-out, mark and cut all pattern and piece parts for Liner, Shell and insulation (not requiring ply-up). Patterns marks on face side of material.

1.1.2 a. Ply-up - four layers of insulation face sides down. HOLD firmly in place.

b. Mark patterns.

c. Using Nomex thread stitch on marks all patterns except boot and brief leg flap which will remain clamped together.

d. Trim out each pattern piece 1/4 to 1/2 inch from stitch line, with the exception of the pieces called out; they will be trimmed 1/4 to 1/2 inch of pattern lines and clamped together.

OPERATION 1.2 - PLEATING AND WRAPPING INSULATION

1.2.1 Pleating - Lay insulation face side down. Fold insulation on pleating marks. Place pieces of film tape approximately one inch long on folded pleats to hold in place on quarter marks only. See figure (1.2a) below:

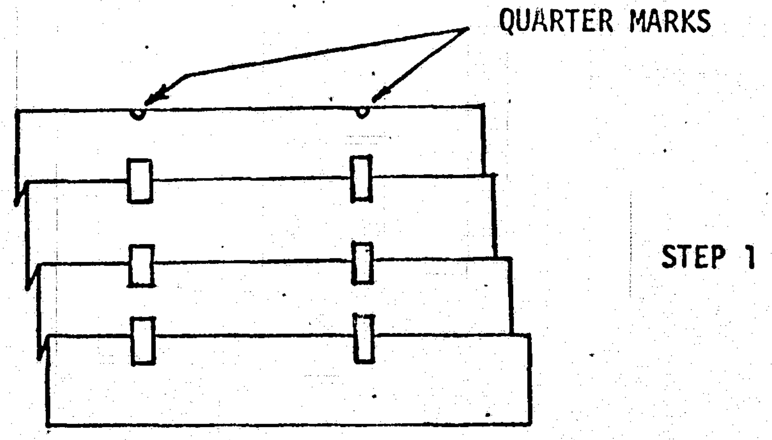


FIGURE 1.2a

1.2.2 a. Cut a length of film tape long enough to extend about one inch beyond the ends of film tape pieces in Step No. 1.

b. Cover tape pieces. See figure (1.2b):

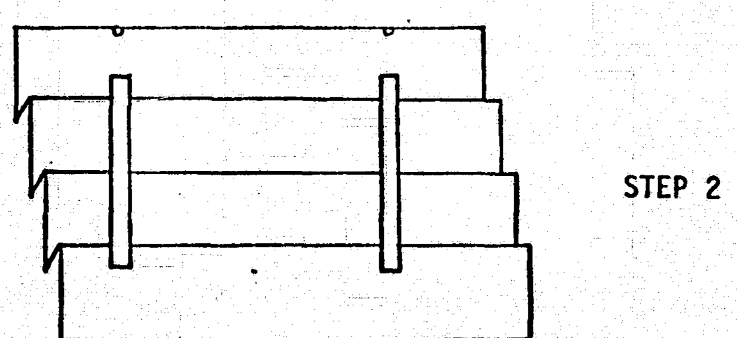


FIGURE 1.2b

1.2.3 a. Turn insulation face side up.

b. Cut film strips approximately same length, covering smaller strips on other side.

c. Locate these film strips in the same location as film strips on opposite side and position over all folds. See figure below (1.2c):

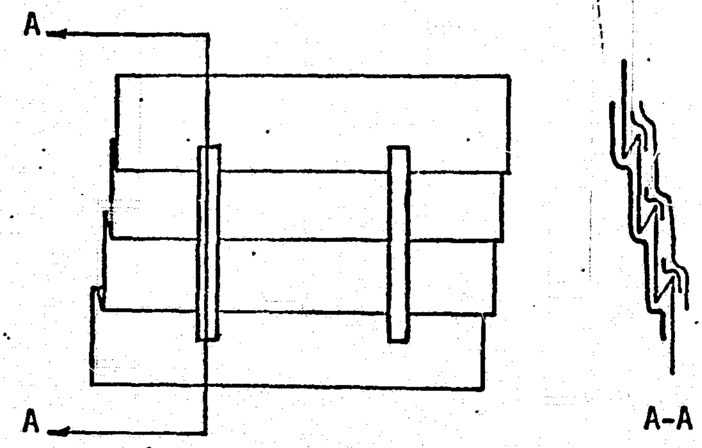
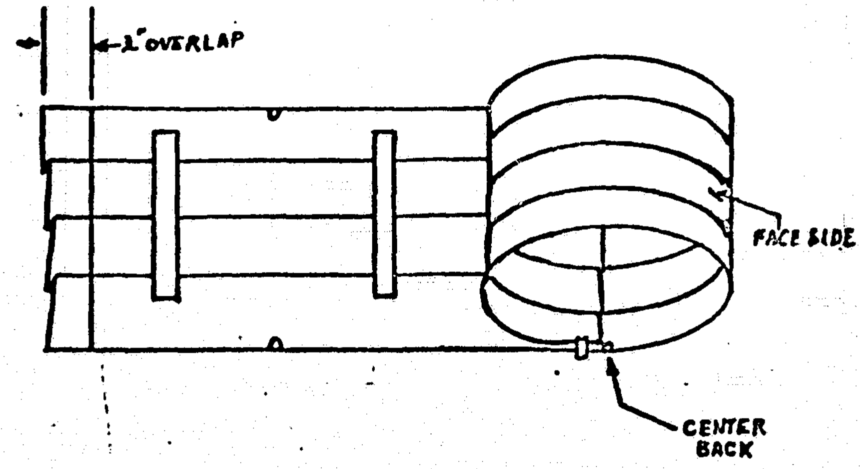


FIGURE 1.2c

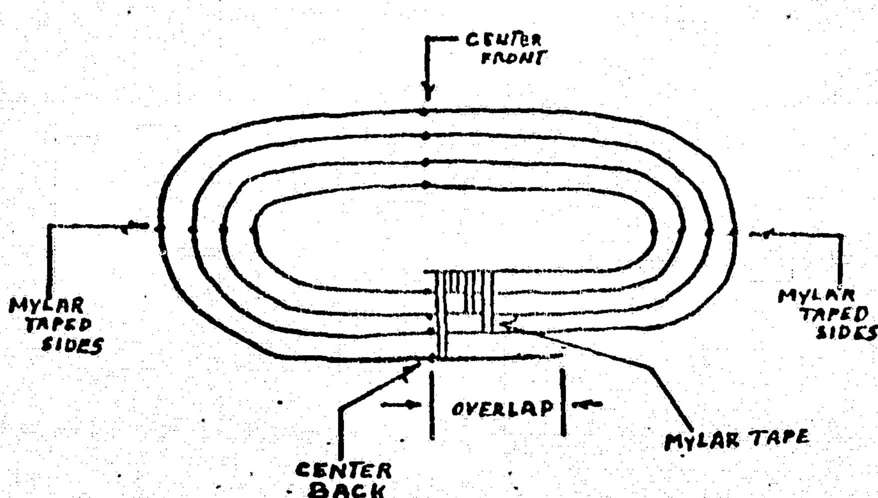
1.2.4 Wrapping -

a. The insulation to be wrapped will always be folded toward the end with the two inch overlap.

b. Place insulation face side down. Starting from the end without the two inch overlap, fold, aligning center front to center front and center back to center back. (See sketch on top of next page)



c. Place small piece of film tape approximately one inch long next to the alignment marks to hold wrapping. Do not cover marks. The two inch overlap finishes on the center back.



OPERATION 1.3 - LEG ASSEMBLIES

1.3.1 a. Join knee section front together.

b. Join knee section front to upper leg cone front and lower leg cone front.

c. Join lower leg back to leg front.

d. Join ankle to lower leg and lower back.

1.3.2 a. Join liner boot insert to liner lower boot.

b. Join lower boot and insert to ankle.

1.3.3 Join inside seam from top of leg to bottom of boot.

1.3.4 Install slider half of zippers to boot on pattern marks. Stitch 3/8" from edge with Nomex thread.

NOTE: Left boot toe and heel zippers close clockwise.
Right boot toe and heel zippers close counter-clockwise.

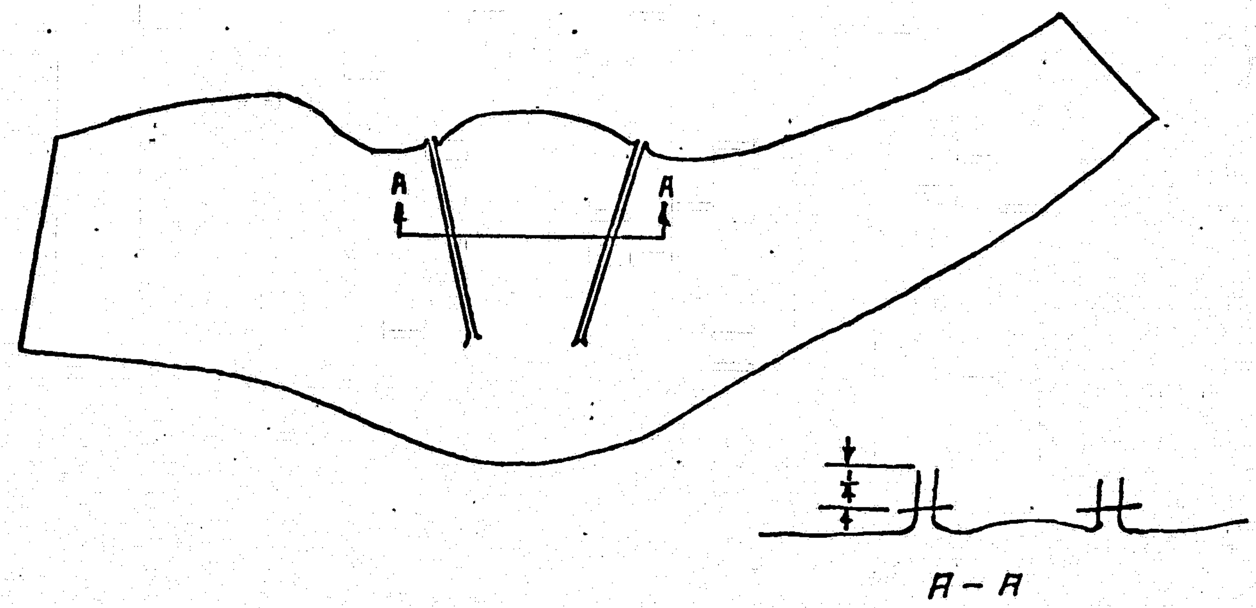
1.3.5 Turn under one loop each end of three inch and four inch loop tape. Position on pattern mark of boot, loops facing bottom of boot and stitch 1/16 inch all around flat part of loop tape being careful not to close loops.

Insulation

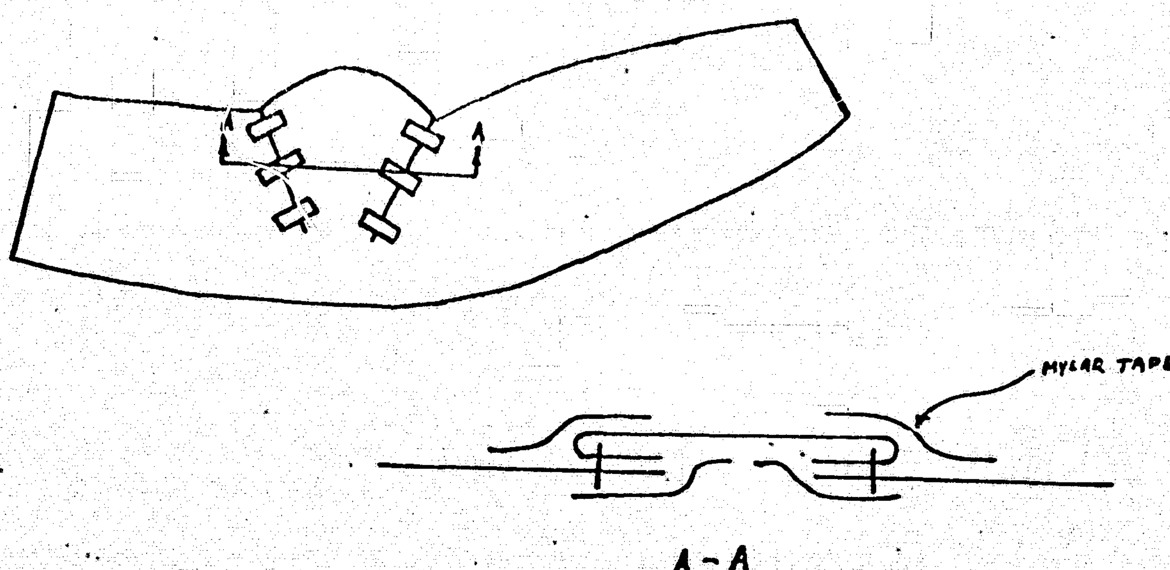
1.3.6 Take wrapped leg insulation and stitch a single row of stitches around bottom 1/4 inch from raw edges using Nomex thread.

1.3.7 Take ply-up boot insulation still clamped together. Stitch 1/8 inch from pattern line all around except at bottom. Stitch on pattern line along bottom. Trim insulation on pattern line all around boot except bottom. At bottom of insulation, trim insulation 1/4 to 1/2 inch of stitch line.

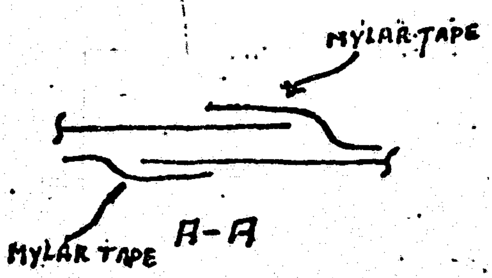
1.3.8 Join darts of boot insulation ply-up, wrong sides together and stitch 1/4 inch from raw edges.

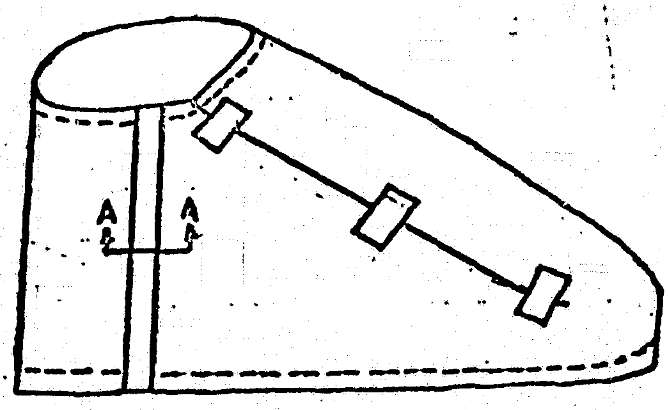


1.3.9 After stitching darts, fold over on pattern marks located on wrong side of insulation. Place piece of film tape approximately one inch long across fold on wrong side and face side to hold folds.



1.3.10 With face of insulation up, fold ends of boot raw edges to overlap. Tape with film tape the entire length of overlap. Turn insulation face side out and tape overlap.





Shell

1.3.11 a. Join Knee Sections together.

b. Join supper leg cone and bottom leg cone to Knee Sections.

c. Join front leg to the lower leg back at the outside seam only.

d. Join ankle boot to bottom of leg front and back.

e. Join insert boot to lower boot.

f. Join lower boot and insert to ankle.

g. Close shell by joining the inside seams.

1.3.12 a. Turn leg shell face side out.

b. Position a piece of lacing cord around inside bottom of boot shell on pattern marks. Fold shell over cord one inch. Using a zipper foot stitch, as close to cord as possible, holding to pattern marks. Use Nomex thread.

Leg Assembly

1.3.13 a. Slip boot insulation face side out over rubber side of boot liner joined to leg liner. Align raw edge of liner to stitching around bottom of boot insulation, matching quarter marks, stitch 1/8 inch from raw edge of line using Nomex thread all around boot bottom.

b. Trim off bottom of boot insulation even with edge of liner.

1.3.14 With leg shell face side out and leg liner with boot insulation rubber side out, slip leg shell into liner leg. Align raw edges of boot liner and insulation with edges of boot shell. Join 1/2 inch from edges using Teflon thread.

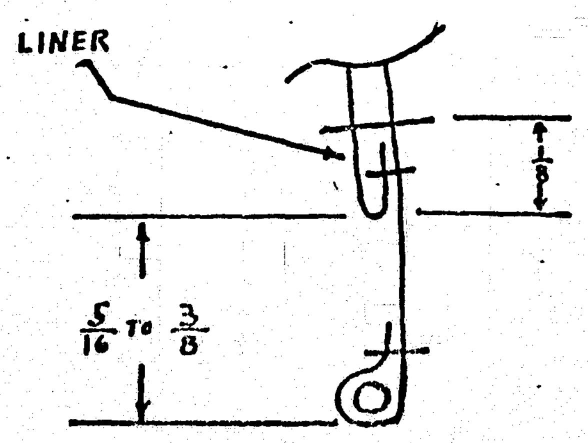
1.3.15 Slip wrapped leg insulation unstitched end to top of leg over liner. Overlap of insulation is to back of leg. Align quarter-marks, raw edges of insulation with raw edge of leg liner. Stitch 1/8 inch from raw edges joining insulation and liner using Nomex thread. The entire leg and boot should now be covered with insulation, face side out.

1.3.16 Before joining leg insulation and boot insulation, hold leg assembly at top and bottom, pull lightly apart at the same time bending slightly to the back so as to spread pleats to insure there is enough easement. Aligning sides and front, place strips of

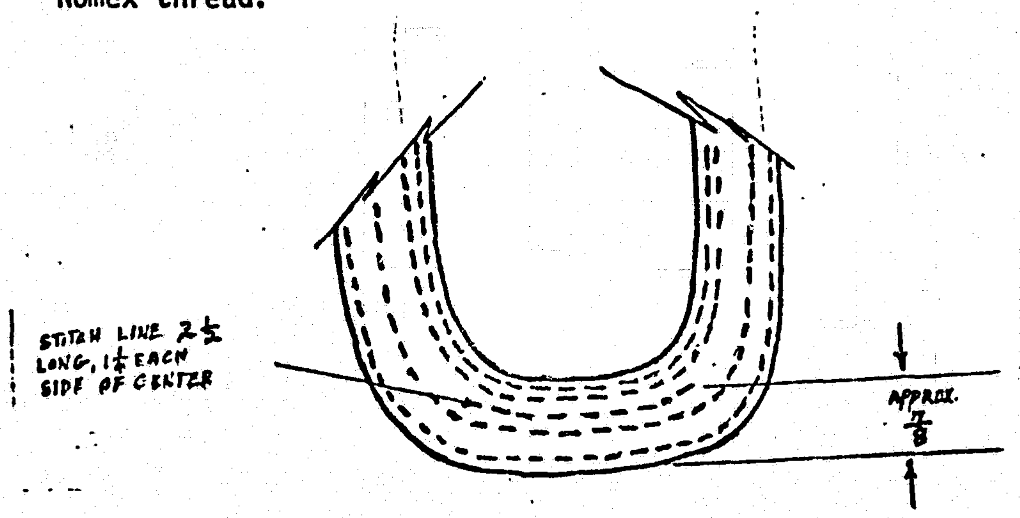
film tape joining the two pieces of insulation between quartermarks. (The insulation is free of stitching between top of leg and boot bottom.)

1.3.17 Pull leg shell out from inside of leg liner and insulation and gently work shell over outside of leg liner and insulation, insuring sides, front and back and boot are all aligned properly. It may be necessary to maneuver insulation to insure it is not wrinkled or bunched up.

1.3.18 Gently fold out bottom of boot exposing liner. There should be approximately 5/16 to 3/8 inch from liner fold to end of shell. Stitch 1/8 inch from liner fold through liner, insulation and shell using Nomex thread.



1.3.19 To prevent shell from riding up at bottom of boot when installed, locate center heel and center toe, measure up from bottom of boot 7/8 inch on shell and stitch one continuous stitch 1-1/4 inch each side of center through shell, insulation and liner using Nomex thread.



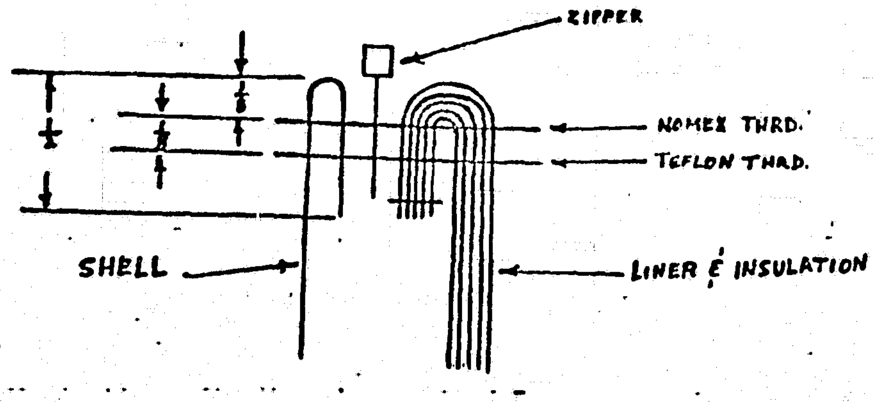
1.3.20 Install zipper at top of leg.

a. Turn under shell and liner 1/2 inch towards each other.

b. Install slider half of 24-3/4 inch long zipper between shell and liner positioning at start and stop pattern marks.

NOTE: Zipper installed in right leg closes around front to back. Left leg zipper closes from back to front.

(See sketch at top of next page)



Leg assembly is now completed.

OPERATION 1.4 BRIEF

1.4.1 Install 1 inch by 1-1/2 inch velcro pile pieces to pattern marks on cloth side of brief front and side liner pieces and stitch 1/16 inch from raw edge of velcro all around using Nomex thread.

1.4.2 Position brief liner pieces within stitch line on insulation ply-up. Rubber side of liner to wrong side of insulation. Sew liner to insulation, stitching 1/8 inch from raw edge of lines using Nomex thread.

1.4.3 Trim insulation even with liner raw edges.

1.4.4 a. Join left brief front to left beief back at sides with 1/4 inch seam on cloth side. Repeat for fight side.

b. Join left and right center back and left and right center back and left and right center front. Crotch with 1/4 inch seam on cloth side using Nomex thread.

NOTE: Do not topstitch.

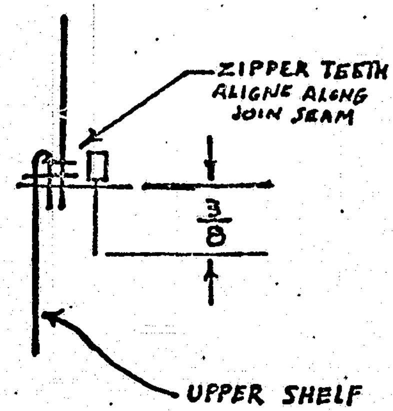
c. Turn brief insulation side out.

1.4.5 a. Join liner upper shelf band to liner upper shelf. The upper shelf band is larger than upper shelf, therefore, to match up quartermark, the band will have to be worked to the upper shelf and distributed evenly between quartermarks. Turn seam down and topstitch.

b. Join ends and topstitch.

1.4.6 Position 20 velcro pieces 1" X 1-1/2" around liner upper shelf band on pattern marks. Using Nomex thread, stitch 1/16 inch from velcro raw edge.

1.4.7 Install slider half of 50 inch zipper to the upper shelf band aligning top of zipper teeth along join seam of upper shelf and upper shelf band, and stitch 3/8 inch from straight edge of zipper tape. Slider should be next to liner, and zipper should close from center back to left around front. Do not sew across center back seam. Stop and start on each side of seam.

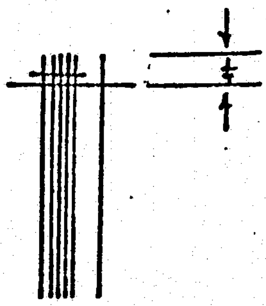


1.4.8 a. Join side seams of liner waist front and liner waist back, turn seam to back and topstitch.

b. Join top of liner waist to upper shelf, turn seam down and topstitch.

1.4.9 On waist pleated and wrapped insulation, stitch 1/4 inch from raw edge on <u>bottom only</u>.

1.4.10 a. With rubber side to face side of insulation, join liner waist to top of lower brief liner and insulation 1/4 inch from raw edge. DO NOT TOPSTITCH.

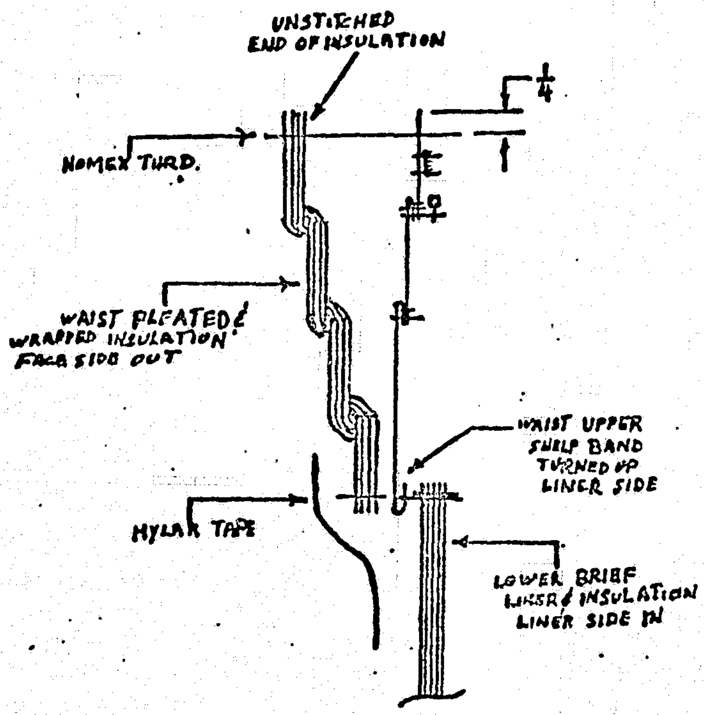


b. Turn liner waist up and away from lower brief liner and insulation where joined.

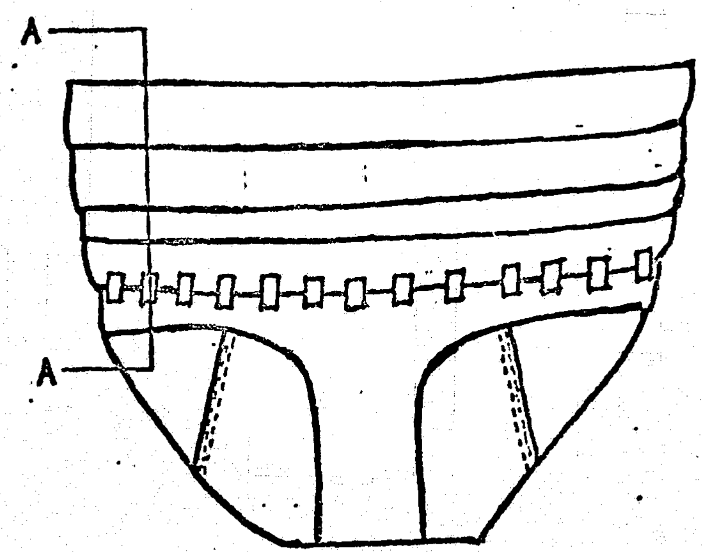
c. Slip pleated and wrapped waist insulation, face side out, over waist upper shelf. Sewn end of insulation toward lower brief. Align raw edges of unsewn end of insulation with raw edges of waist upper shelf band. Match center front, center back and side quarter marks and stitch 1/4 inch from raw edges.

d. Overlap waist insulation over brief and install 32 pieces of one inch long film tape, first on quarter mark and then evenly distributed between quarter marks.

(See sketch on next page)



A-A



1.4.11 a. Position brief leg flap liner rubber side to insulation within marked pattern line. Stitch across top following stitch line, down along sides and bottom, 1/8 inch from raw edge of liner.

b. Trim excess insulation on sides and bottom even with liner raw edge. At the top, fold liner away from insulation and trim insulation across top, 1/8 inch from stitch line.

1.4.12 Lower Brief Shell

a. Join left brief front and left brief back at sides. Repeat for right.

b. Join left and right above pieces at center front, center back and in crotch.

c. Join upper shelf band to upper shelf. The upper shelf band is larger than upper shelf, therefore, to align quarter marks, the upper shelf band will have to be worked onto the upper shelf, distributed evenly between quartermarks.

d. Join ends of upper shelf and band.

e. Join sides of waist front and waist back.

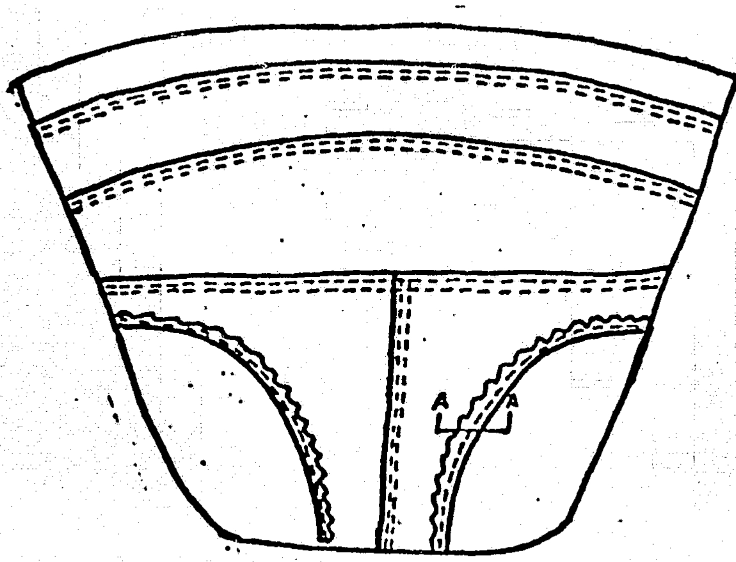
f. Join top of waist to upper shelf.

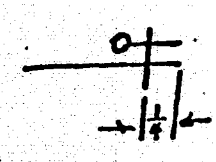
g. Join waist to top of brief.

1.4.13 Brief Leg Flap

a. Join left brief leg flap ends, overedge, join seam completely around flap. Top stitch. Repeat for right leg flap.

1.4.14 Install a piece of 35 inch loop tape around leg openings on face side of lower brief shell. Align straight edge of loop tape with raw edge of shell, loop facing away from leg opening. Stitch one row of stitch 1/4 inch from raw edges using Nomex thread. There should be a two loop overlap.

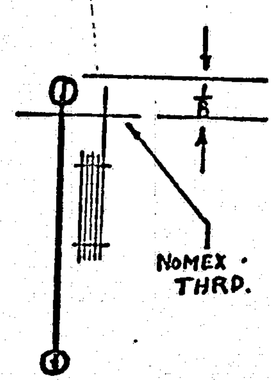




A - A

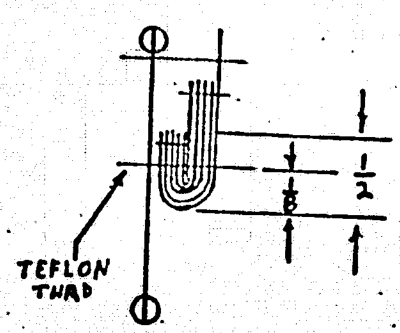
Brief Assembly

1.4.15 a. Join liner and insulation leg brief to shell leg flap, face side of insulation to wrong side of shell. Align the raw edge of liner end without insulation to top edge of shell and stitch 1/8 inch from edges using Nomex thread.



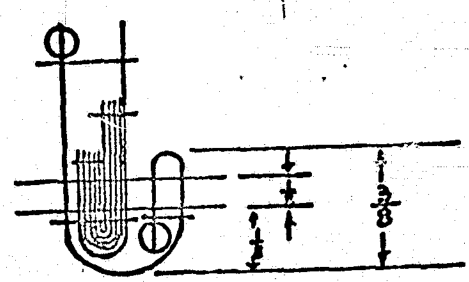
b. At the straight edge (bottom) of shell flap, measure from raw edge 3/4 inch around inside of shell.

c. Turn liner and insulation under toward shell 1/2 inch and position fold on 3/4 inch marks on shell. Stitch 1/8 inch from fold using Teflon thread.



d. Turn raw edge of shell under, toward liner 3/8 inch and baste to hold along edge of overedging. Use Nomex thread.

e. Turn folded edge of shell over liner and insulation 3/8 inch and stitch one row of stitches 1/8 inch from fold and a second row of stitches 1/8 inch from first row using Nomex thread.



1.4.16 Join brief leg flap assembly to brief leg openings. Stagger flap join seam with crotch join seam. Turn under top of flap raw edge 1/2 inch, position fold to pattern marks and quarter marks. Stitch, starting from crotch seam, 1/8 inch from fold of flap using Teflon thread. Stitch second row 3/8 inch from first row using Nomex thread.

1.4.17 Join shell brief to liner and insulation.

a. Measure down 3/4 inch from inside top of shell and mark all around opening.

b. Slip liner and insulation into shell (insulation to shell). Align front, back and sides. Turn top of liner and insulation under towards shell 1/2 inch and position fold along 3/4 inch mark. Stitch 1/8 inch from fold of liner using <u>Teflon thread.</u>

c. Turn top of shell under 3/8 inch to liner, baste stitch along edge of overedging to hold in place, using Nomex thread.

d. Turn folded shell over liner 3/8 inch and stitch 1/8 inch from fold using Nomex thread.

1.4.18 Join liner and insulation to brief leg openings by aligning raw edges of liner and insulation with bottom of loops on looptape and stitch 1/8 inch from raw edges using Teflon thread. Stitch second row 1/8 inch from first row using Nomex thread.

OPERATION 1.5 HIP ASSEMBLIES

1.5.1 Liner Assembly

a. Join bottom of hip flange to top upper section.

b. Join bottom of upper section to top middle section.

c. Join bottom of middle section to top of lower section.

d. Join bottom of lower section to top of thigh overlap piece.

e. Turn seams and top stitch using Nomex thread.

f. Join side seams, turn to back and top stitch.

1.5.2 Shell Assembly

a. Join bottom of hip flange to top upper section.

b. Join bottom of upper section to top of middle section.

c. Join bottom of middle section to top of lower section.

d. Join bottom of lower section to top of thigh overlap piece.

e. Overedge all join seams and top stitch.

f. Join side seams, overedge and top stitch.

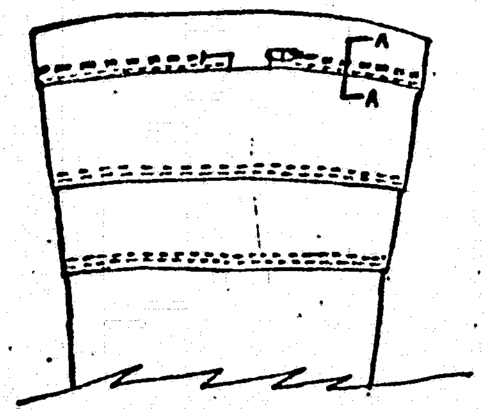
1.5.3 Install zipper to liner assembly.

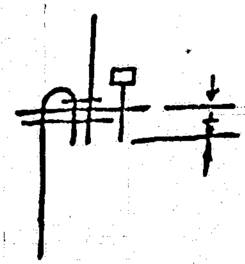
a. Position slider half of zipper 32-1/2 inches long on pattern marks, aligning straight edge of zipper tape with raw edge of hip flange and upper section seam, zipper teeth facing toward top. Stitch 1/4 inch from straight edge using Nomex thread.

NOTE: Right liner assembly - zipper closes to outside.
Left liner assemlby - zipper closes to inside.

b. Turn liner assembly face side out.

(See sketch on top of next page)





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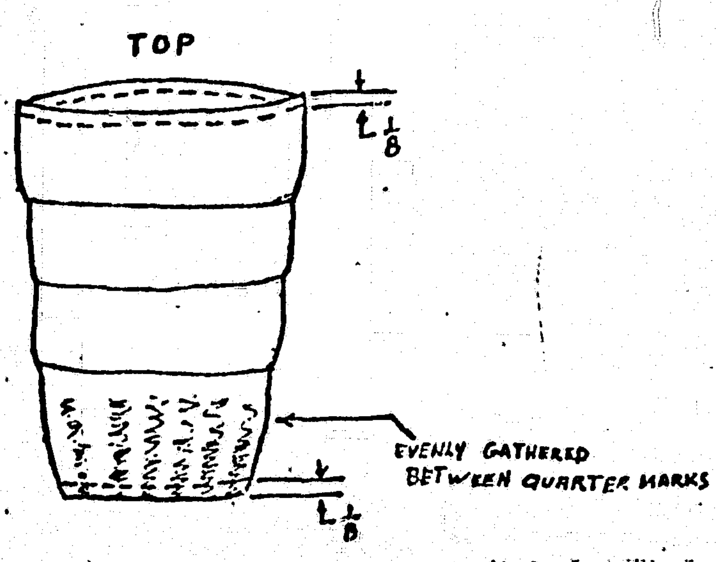
1.5.4 Join liner and insulation:

Insert liner inside of pleated and wrapped insulation making sure front is to front and top and bottom align. Align liner and insulation raw edges and sew 1/8 inch from raw edges at top. At the bottom, the insulation is larger than the liner. Locate the quarter mark on the liner and insulation and gather liner evenly between quarter marks stitching 1/8 inch from raw edges. Use Nomex thread. (See sketch on top of next page)



1.5.5 Join Liner and Insulation to Shell

a. Measure 3/4 inch from edges of top and bottom of shell on inside and mark all around.

b. Measure 1/2 inch from edge of top and bottom of liner and mark all around.

c. Slip shell, face side out, over liner and insulation. Insulation agsinst inside of shell.

d. The following operation will be accomplished at top and bottom of assembly:

1. Turn liner and insulation under toward shell 1/2 inch.

2. Position fold of liner along 3/4 inch marks on shell and stitch 1/8 inch from fold of liner using <u>Teflon thread</u>.

3. Turn shell under 3/8 inch to liner and baste to fold along edge of overedging using Nomex thread.

4. Turn basted fold of shell over liner 3/8 inch and stitch 1/8 inch from fold using Nomex thread.

e. After completing above operation (d), stitch one row of stitches using Nomex thread 1/8 inch from join seam of hip flange to upper section through all materials.

NOTE: 1. Insure liner is flat, no wrinkles.

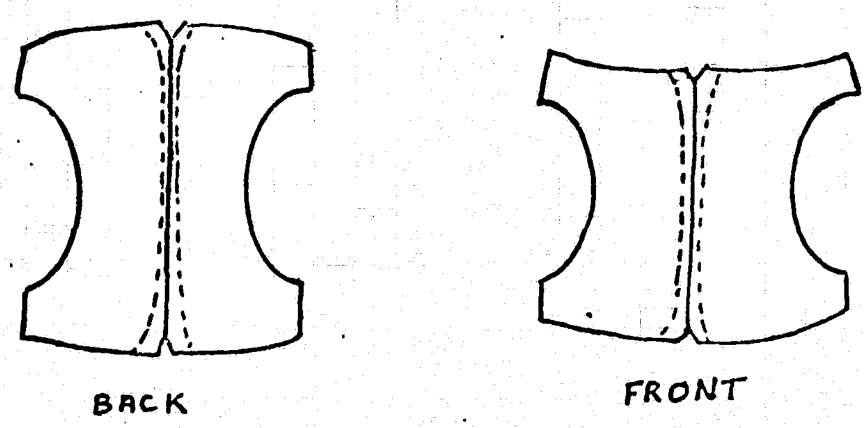
2. Do not sew through zipper.

OPERATION 1.6 TORSO ASSEMBLY

1.6.1 Liner and Insulation

Fold torso front liner on center marks and stitch a dart on pattern marks using Nomex thread.

1.6.2 Fold liner torso back on center marks and stitch a dart on pattern marks using Nomex thread. Tie off thread ends and coat.



1.6.3 Join torso liner front and back.

1.6.4 Install 22 pieces of velcro pile 1 inch by 1-1/2 inch long on pattern marks 1/16 inch from edge using Nomex thread.

1.6.5 Trim excess bladder at each end of darts front and back to within 1/4 inch of stitching. The center area of dart is within 1/4 inch; therefore, it will not be necessary to trim.

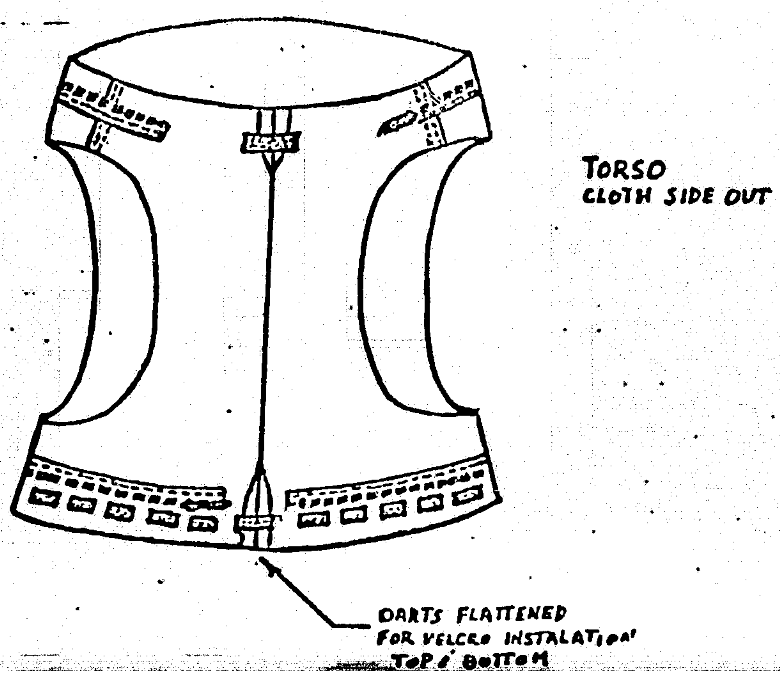
1.6.6 Install slide fastener waist:

Align straight edge of slider half zipper tape along pattern marks above velcro pieces, teeth facing down toward waist. Slider will close counter clockwise (from left front of torso around back to stop on right front). Stitch 3/8 inch from straight edge of zipper tape using Nomex thread.

1.6.7 Install slide fastener neck:

Align straight edge of slider half zipper tape along pattern marks at neck, zipper teeth facing up. Slider will close counter clockwise. Stitch 3/8 inch from straight edge of zipper tape using Nomex thread.

1.6.8 Center piece of velcro 1 inch wide by 1-3/4 inch long over center front seam at neck of torso liner front, on cloth side, top of velcro 1/2 inch from lower raw edge, stitch 1/16 inch from raw edge of velcro piece all around. Flatten dart under velcro.

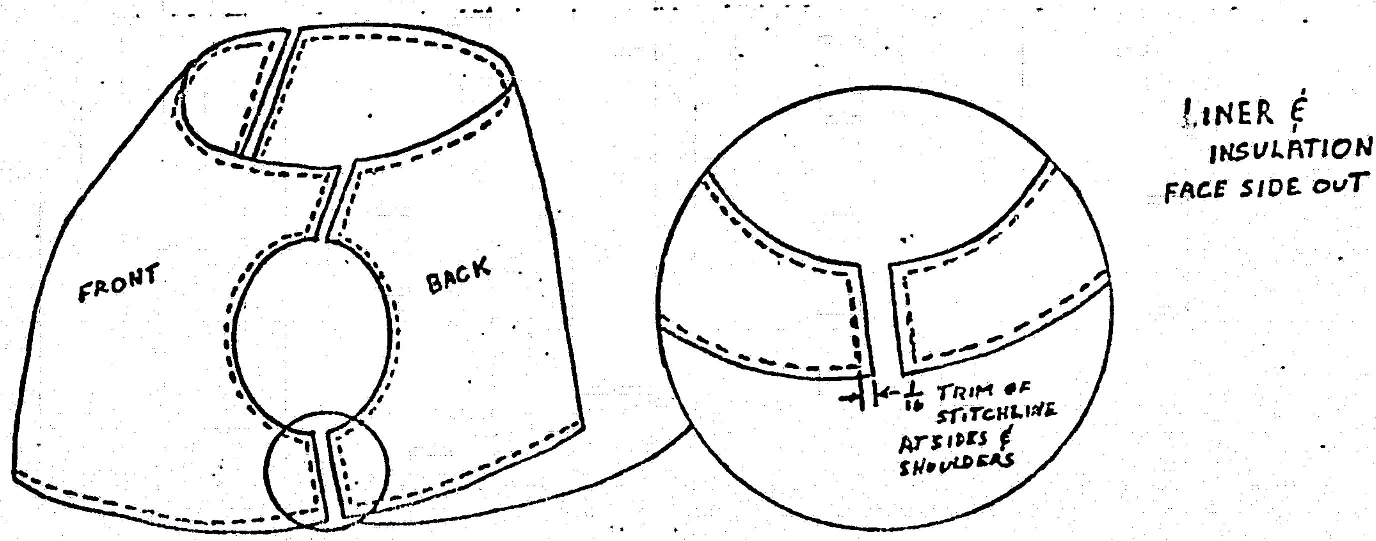


1.6.9 Insulation

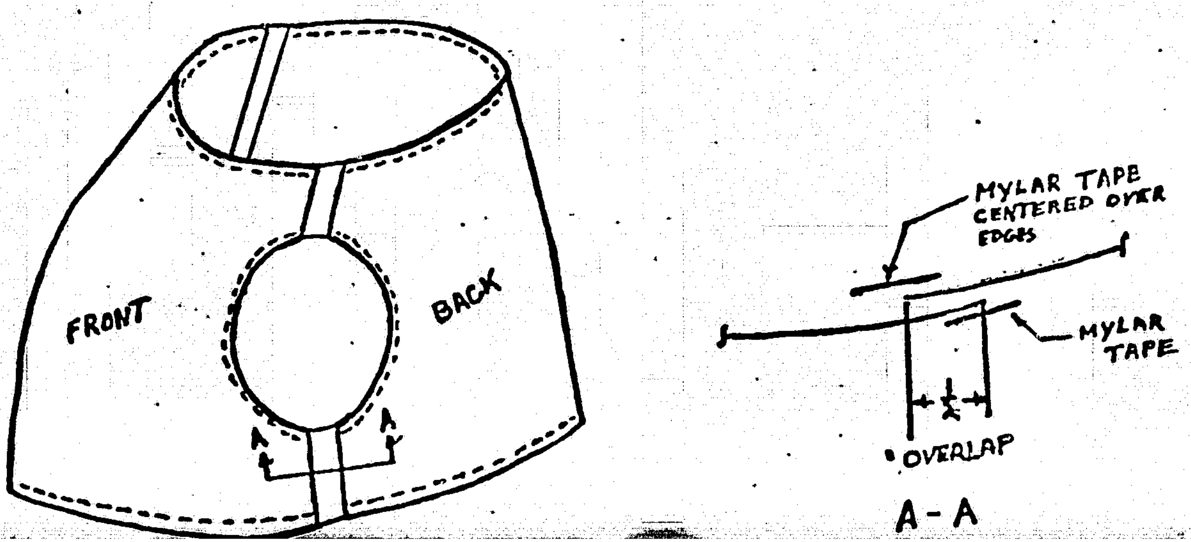
Sides and shoulders trim to within 1/16 inch of stitch line, shiny side out. Overlap front to back 1/2 inch. Center film tape over the overlap, inside and out.

1.6.10 Slip liner inside insulation, rubber side to unshiny side of insulation. Align raw edge of liner with stitch line on insulation and stitch 1/8 inch from liner, using Nomex thread. Torso bottom, neck opening and arm opening.

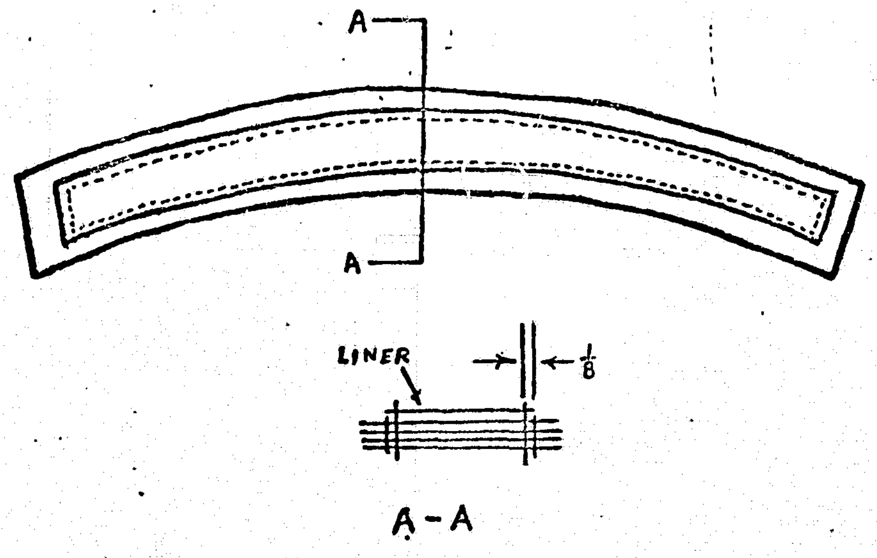
NOTE: Be sure to line up pattern marks as insulation excess has to be fed on to liner.



1.6.11 After trimming, overlap front to back 1/2 inch. Center film tape to overlapped seams.



1.6.12 Lay ply-upped torso, insulation flange left and right shiny side down. Position liner rubber side down within stitch line around insulation. Stitch 1/8 inch from raw edge of liner all around. Trim insulation even with raw edge of liner.



1.6.13 Join torso flange ends (one for each arm) insulation (shiny side) together and stitch 1/4 inch from raw edges. Do not top stitch. Use Nomex thread.

1.6.14 Join torso liner and insulation flanges to arm openings. Insulation together align edge of flange to edge of arm opening, insuring all pattern marks align and stitch 1/4 inch from edge using Nomex thread. After stitching flanges to torso, turn out through arm opening. DO NOT TOP STITCH.

Torso Shell

1.6.15 Gas Connector Openings:

Overedge two back and one front valve opening shell reinforcement.

1.6.16 Join left and right front shell pieces at center front, face sides together.

1.6.17 Join left shell back and right shell back at center back, face sides together.

1.6.18 Join front and back sides together at sides and shoulder.

1.6.19 Overedge all join seams.

1.6.20 Turn shoulder side seams to back, center front and back seams to left and top stitch.

1.6.21 Join ends of shell shoulder flange (one for each arm). Overedge joined edges, turn seams to front and top stitch.

1.6.22 Overedge around neck and bottom and arm openings of shell torso.

1.6.23 Join left and right shoulder flanges to arm opening, face sides together, aligning pattern marks, stitch 1/4 inch from edge using Teflon thread. Turn seams toward flange, top stitch one row stitches 1/8 inch from fold using Nomex thread.

1.6.24 Stitch around pattern marks on liner and insulation of the front and back torso valve locations, using Nomex thread. Insure that insulation is flat and does not bunch up or wrinkle prior to sewing.

1.6.25 Stitch around pattern marks of the two small valve locations in front and two large valve locations in back of torso shell.

1.6.26 Position shell valve reinforcement on shell torso, face sides together, aligning centers of reinforcement to center mark of torso. Stitch reinforcement to shell following around pattern marks. Use Nomex thread. Coat stitches with Fluorocarbon Resin (Kel-F-800) completely.

1.6.27 a. Position a two inch punch centered evenly within stitch line of torso liner and insulation back valve locations and punch out hole.

b. Position a 1-7/16 inch punch centered within stitchline of valve location of torso liner and insulation front and punch out hole.

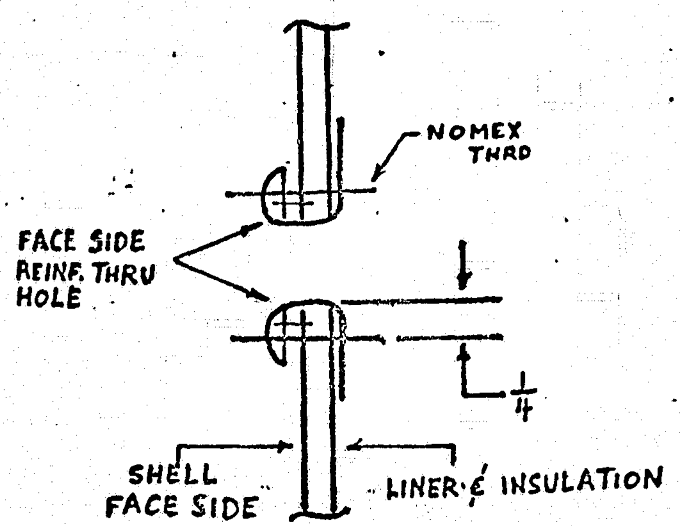
c. Punch out torso shell front and back valve locations using same size punches.

1.6.28 Torso Assembly

a. Slip torso liner and insulation into torso shell, face side of insulation against wroung side of torso shell. Align top, bottom sides and punched out hole locations.

b. Turn torso shell, liner side out. Turn reinforcement thru punched out hole onto liner, stitch 1/4 inch from fold around hole on shell side, through all layers, using Nomex thread.

(See sketch on top of next page)



Perform same operation to all valve hole locations.

c. Close up torso assembly:

1. On the outside edges of the torso shell, neck bottom and arm opening, measure from edges 3/4 inch and mark on wrong side of shell around all openings mentioned above.

2. Neck and Bottom Openings: Turn liner and insulation under toward shell 1/2 inch and position fold along 3/4 inch marks on shell. **Stitch 1/8 inch from fold of liner using Teflon thread.**

3. <u>Arm Openings</u>: Turn liner and insulation under toward shell 1/4 inch and position fold along 3/4 inch marks on shell and stitch 1/8 inch from fold of liner using teflon thread.

4. <u>All torso neck, bottom and arm openings</u>: Turn shell under toward liner 3/8 inch. Baste to hold in place. Fold basted shell over liner 3/8 inch and stitch 1/8 inch from fold using Nomex thread.

OPERATION 1.7 SHOULDER ASSEMBLY

1.7.1 Liner and Insulation Assembly

a. Join bottom of upper section to top of upper middle section.

b. Join bottom of upper middle section to top of lower middle section.

c. Join bottom of lower middle section to top of lower section.

d. Join bottom of lower section to top of upper arm flange.

1.7.2 Join shell face side to face side:

a. Join bottom of upper shoulder section to top of upper middle section.

b. Join bottom of upper middle section to top of lower middle section.

c. Join bottom of lower middle section to top of lower section.

d. Join bottom of lower section to top of upper arm flange.

e. Overedge all join seams and top stitch.

1.7.3 Join side seams, overedge and top stitch.

1.7.4 a. Install two zippers, each arm, 11 inches long to the shoulder liner assembly at the top on pattern marks.

NOTE: On the right arm, the zipper to the right of front seam closes around the outside to the back. The zipper on the left side of the front seam, closes from the back of the arm around to the front.

b. Stitch 3/8 inch from straight edge of zipper tape using Nomex tape.

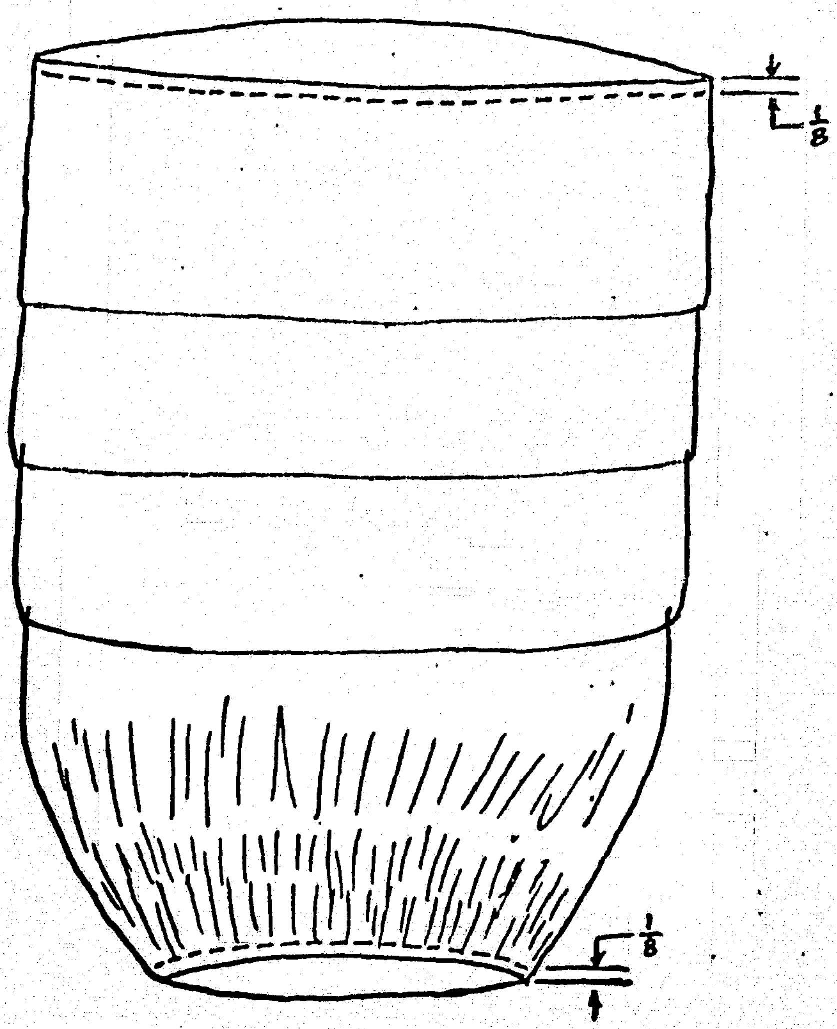
c. The left arm zipper is located in the same position.

1.7.5 Join liner and insulation:

a. Insert shoulder liner rubber side out into insulation shiny side out. Align front seams and quarter marks. Folds facing down.

b. Align liner and insulation raw edges at top and stitch 1/8 inch from raw edges using Nomex thread.

c. At the bottom, the insulation will be larger than liner; therefore, the excess insulation will be worked evenly into the quartermarks, aligning raw edges and stitching 1/8 inch from raw edge using Nomex thread.

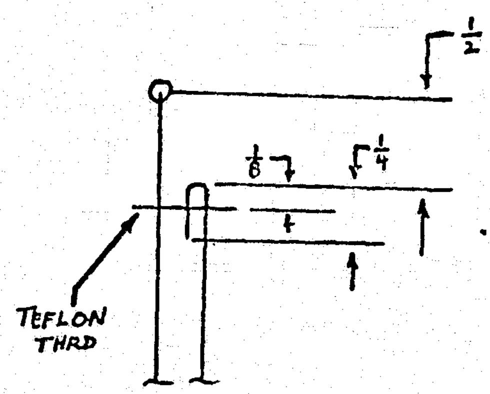


1.7.6 Shoulder Assembly

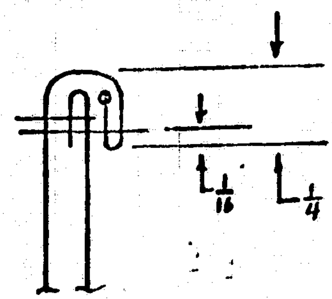
a. With shell shoulder right side out, slip over liner and insulation assembly. Align front seams and quartermarks, top and bottom.

b. At the bottom end, measure from raw edge of shell 1/2 inch and mark all around.

c. Turn under liner and insulation 1/4 inch toward shell. Align fold along 1/2 inch marks (do not pin or baste) and stitch 1/8 inch from fold using teflon thread.

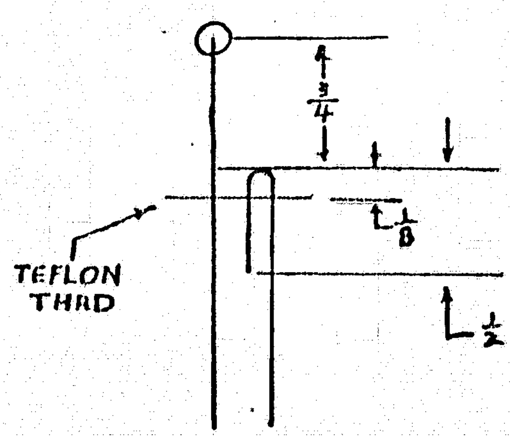


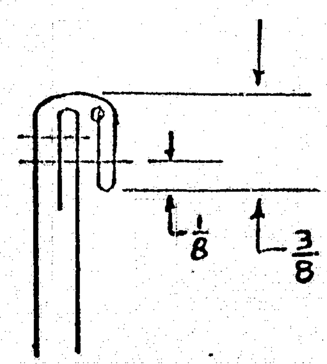
d. After completing liner to shell, fold shell to top of liner 1/4 inch and baste stitch to hold. Turn basted fold over liner 1/4 inch and stitch 1/16 inch from fold using Nomex thread. (See sketch on top of next page)



e. At top of shoulder measure from inside raw edge of shell 3/4 inch and mark all around.

f. Fold edge of liner toward shell 1/2 inch and align with 3/4 inch marker on shell and stitch 1/8 inch from fold all around using teflon thread.





g. Fold edge of shell 3/8 inch to fold of liner and top stitch to hold. Fold shell again 3/8 inch over liner and stitch 1/8 inch from fold using Nomex thread. See above sketch.

OPERATION 1.8 <u>LOWER ARM ASSEMBLIES</u>

1.8.1 Liner and Insulation

a. Join bottom upper section back to top of middle section back.

b. Join bottom of middle section back to top of lower section back.

c. Turn seams down and top stitch.

d. Join front section to back sections at sides.

e. Turn seams to back and top stitch.

1.8.2 Install 16 pieces of 1 inch by 1-3/8 inch velcro; eight at elbow and eight at wrist end of liner on pattern marks. Stitch 1/16 inch from raw edges of velcro with Nomex thread.

1.8.3 Install zipper to liner

NOTE: 1. Zipper installed in left arm will be without the slider half. Future fabrication zipper should be installed with the slider half.

2. Right arm will have slider half of zipper installed.

3. Zipper will close on left arm counter clockwise and on the right arm the zipper will close clockwise.

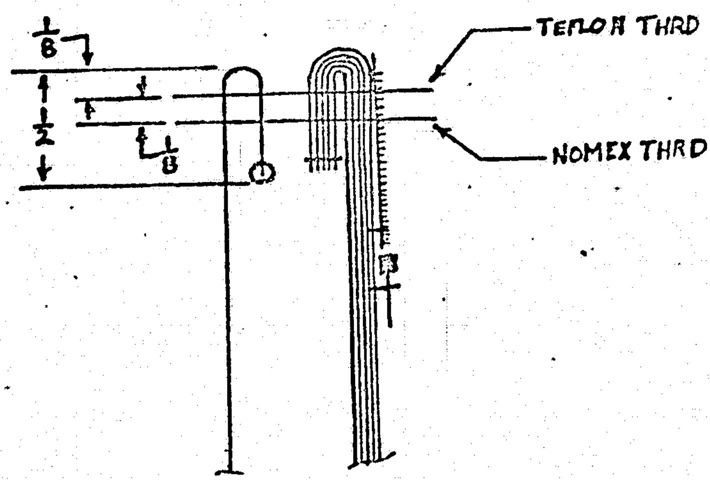
Position zipper on pattern mark at elbow end of arm, teeth of zipper facing elbow end. Stitch 3/8 inch from straight edge of zipper tape.

1.8.4 Slip pleated and wrapped insulation face side out over rubber side of liner. Align front, back, sides, elbow and wrist ends with liner. Stitch at elbow end and wrist end of liner and insulation together 1/8 inch from raw edges.

1.8.5 Lower Arm Assembly

a. Slip lower arm shell, face side out over face side of liner and insulation. Align front, back, sides, wrist, and elbow ends.

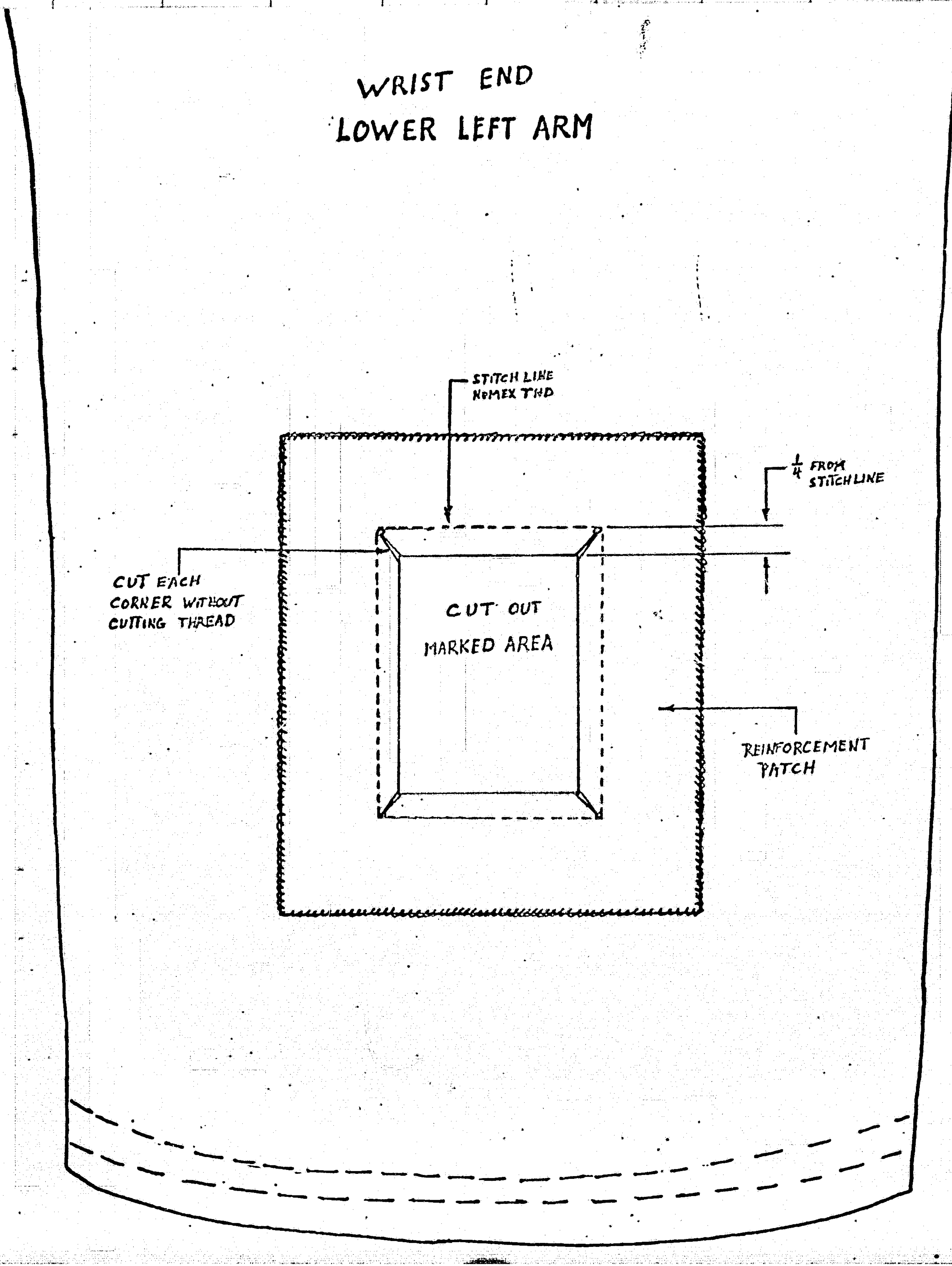
b. Turn under shell and liner and insulation at wrist and at elbow ends 1/2 inch towards each other. Stitch first row of stitches 1/8 inch from fold using <u>Teflon thread</u>. Stitch second row 1/8 inch from first row using <u>Nomex thread</u>.

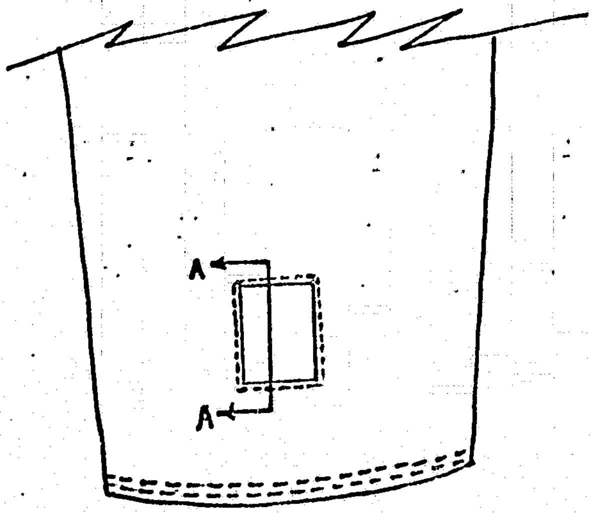


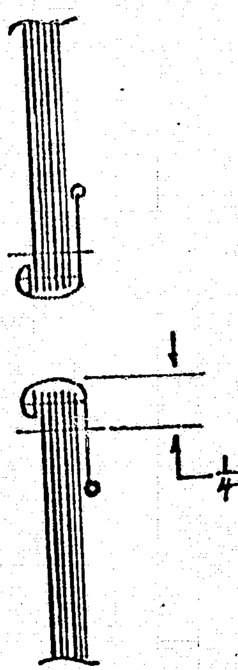
1.8.6 Install Pressure Gauge Reinforcement in Left Lower Arm

Overedge reinforcement piece around all edges. Position on lower left arm at wrist end face side to face side. Match two center circular pattern marks. On wrong side of reinforcement there are four small circular marks. Draw a line to the outside of all four marks, this

will be the stitch line. Stitch around marked line using Nomex thread. Measure in from stitch line 1/4 inch all around and mark. Cut out through all materials around marked line. After cutting out material, snip each corner without cutting thread. Turn reinforcement through hole onto liner and stitch 1/4 inch from fold all around using Nomex thread. See attached sketches. This completes assembly of TMG.


WRIST END
LOWER LEFT ARM
STITCH LINE NOMEX THD
1/4 FROM STITCHLINE
CUT EACH CORNER WITHOUT CUTTING THREAD
CUT OUT MARKED AREA
REINFORCEMENT PATCH





A - A

1.9 RINGS, GAS CONNECTOR

1.9.1 Cut out two pieces of Fluorel Rubber (L-4993-4) 2-1/2 inches in diameter.

1.9.2 Center a 1-7/8 inch diameter punch within the 2-1/2 inch diameter rubber pieces and punch out leaving two rings.

1.9.3 Place rings in mold and put mold in Platten Press at 300^{O}F for five minutes.

APPENDIX E

DVT TEST PLAN
FOR THE
ORBITAL EXTRAVEHICULAR SPACESUIT
LIGHTWEIGHT THERMAL
MICROMETEROID GARMENT

INTRODUCTION

This procedure is intended to implement the NASA cycle testing requirements of the Lightweight Thermal Micrometeroid Garment for Space Suits. In addition, this procedure provides for cycle testing of the recently developed scye bearing, provided it is made available. All movements in this procedure are intended to be design limit movements and will be performed as individual joint movements rather than in combination except in the case of the hip flexion, knee flexion and ankle flexion movements which are combined due to their nature.

PURPOSE

This test is being performed to verify the design concepts of the test articles and determine where improvements are needed.

SCOPE

Cycle testing will be conducted on all joints of the suit. Where left and right joints exist, the quantity of cycles called for will be applied to each joint. This test is based on 320 hours EVA use and as such will provide the necessary safety requirements for 320 expected EVA hours. The cycle quantities specified reflect those presented in TIR 744-C-4015A with certain obvious arithmetic corrections having been accomplished. The cycle requirements are shown in Table 1.

PROCEDURE

The cycling will be accomplished per the sequences contained in Attachment I. Sequences will be repeated according to the following schedule:

TABLE I - 320 HOURS OPERATIONAL LIFE

JOINT	EVA HR. WORST CASE SKYLAB *1,2	80 EVA HRS. (2M) *1,5	16 HRS. OVERHEAD (2M) *1,5	CONTINGENCY 32 HRS. (2C) *1,5	2M + 2C	PREFLIGHT PRESS. .125 (2M + 2C) *4	PREFLIGHT VENT .125 (2M + 2C) *4	TOTAL 320 HRS. *4
Shoulder								
Add/Abd *6	11	1,760	3,260	768	5,788	722	722	14,464
Lat/Med	11	1,760	3,260	768	5,788	722	722	14,464
Flex. Ext.	11	1,760	3,260	768	5,788	722	722	14,464
Arm Bearing	11	1,760	3,260	768	5,788	722	722	14,464
Elbow	47	7,520	2,750	2,560	12,830	1,600	1,600	32,220
Hip								
Flexion	7.5	1,200	384	352	1,936	242	242	4,840
Abduction	4	640	240	170	1,050	130	130	2,620
Waist								
Flexion	7	1,120	128	470	1,718	199	199	4,232
Side/side	7	1,120	128	470	1,718	199	199	4,232
Rotation	6	960	96	340	1,396	175	175	3,492
Knee	15	2,400	--	800	3,200	400	400	8,000
Ankle	7.5	1,200	--	--	1,200	150	150	3,000
Boot	7.5	1,200	--	--	1,200	150	150	3,000

*NOTE- REFER TO TABLE I NOTES

TABLE I NOTES

1. CSD-S-018 Skylab cycles were used as the baseline.

2. The highest EVA was used for all EVA activity. (See note 4b below for the complete breakdown on the 160 hours.)

3. The numbers listed are for one joint moving a complete design limit cycle in one plane, i.e., right shoulder flexion/extension.

4. The 160 hours were derived from the following:

a.

Assume	6	flights/year/crewman
	x 4	years (shelf life of suit)
Subtotal	24	flights/crewman/suit life
	x 2/3	ratio of planned Shuttle EVA flights. (Note: All flights to have EVA equipment on board.)
Total	16	EVA flights in 4-year period.
	x 16	hours of EVA/flight (2 planned EVA's--12 hours; 1 contingency EVA--4 hours).
	256	EVA hours in 4-year period/crewman.

Preflight ration = 1/4 of EVA

256 (1/4) = 64

256 + 64 = 320 Total hours/crewman suit in 4-year period.

b. Each crewman has flight suit and backup flight suit. With equal usage, each suit will have 320 -÷ 2 = 160 operational hours/4 years.

The 160 hours is divided into 16 EVA's totaling 96 EVA hours (16 of which use the CSD-S-018 overhead activity), 32 contingency hours and 32 preflight hours (16 pressure and 16 vent).

c. 1) Design Limit Baseline: 160 hours (cycle life)

2) Off-Design Limit Baseline: 320 hours (cycle life)

5. Safety factor of 2 is included in the equation: Total = 2 (M+C) + PF; M = Mission Cycle, C = Contingency Cycle and PF = Preflight Cycle.

6. The shoulder adduction/abduction cycles were assumed to be the same as the other shoulder cycles.

SEQUENCES	REPETITIONS
V-A	100
V-B	60
V-C	40
	Total Vented Repetitions 200
P-A	900
P-B	540
P-C	340
P-D	15
	Total Pressurized Repetitions 1795
	Total Repetitions 1995

Sequences which are prefixed with a V are to be performed in a vented mode, those prefixed with a P are to be performed at a pressure of 4.0 ± .25 PSIG.

The movements to be performed are shown in Attachment II and will be performed to the design limit.

During the conduct of the test, sequences may be combined in any number convenient for the subject, however, the combination of movements will be such that all elements of the sequences are combined in the same manner. In the conduct of the test, the test conductor, technician, subject, or safety representative will stop the test if any condition which adversely affects the health or safety of the test subject is suspected, until the condition can be determined safe or eliminated.

INSPECTIONS

A pretest inspection will be conducted to assure equipment readiness, and in-test inspections will be conducted after the 500, 1000, 1500, sequence repetitions. All in-test inspections will include the following:

A. Visual examination of test articles

B. Hardware actuation verification

C. PRV cracking

D. Hardware cleaning and lubrication, if necessary

E. Removal of the Lightweight Thermal Micrometeroid Garment for inspection

An examination of the test articles will be conducted at the completion of the cycling requirements and disassembly of the test article for examination will be accomplished to the degree deemed necessary by the contract technical monitor and test conductor.

DOCUMENTATION

During the inspections and examinations, photographs will be taken as deemed necessary to document specific areas of interests, as determined by the contract monitor and test conductor. Inspections will be conducted in accordance with the inspection sheets included in Attachment III and discrepancies during the test and inspections will be recorded on the form provided in Attachment IV.

ATTACHMENT I

CYCLING SEQUENCES

SEQUENCE V-A		TOTAL CYCLES REQUIRED VENT.	TOTAL CYCLES REMAINING AT START OF THIS SEQUENCE	TOTAL CYCLES THIS SEQUENCE	TOTAL REMAINING AT SEQUENCE COMPLETION	NUMBER OF CYCLES
1.	Shoulder ab/ad	1444	1444	800	644	8
2.	Shldr. lat/med.	1444	1444	800	644	8
3.	Hip flex/knee/ankle	484	484	300	184	3
4.	Hip abd	260	260	200	60	2
5.	Waist flex	398	398	200	198	2
6.	Side/side waist	398	398	200	198	2
7.	Flex/ext shldr	1444	1444	800	644	8
8.	Arm bearing	1444	1444	800	644	8
9.	Elbow flexions	3200	3200	1700	1500	17
10.	Rotation waist	350	350	200	150	2
11.	Boot	300	300	200	100	2
12.	Knee	300	300	200	100	2

REPEAT SEQUENCE 100 TIMES

SEQUENCE V-B	TOTAL CYCLES REQUIRED VENT.	TOTAL CYCLES REMAINING AT START OF THIS SEQUENCE	TOTAL CYCLES THIS SEQUENCE	TOTAL REMAINING AT SEQUENCE COMPLETION	NUMBER OF CYCLES
1. Shoulder ab/ad	1444	644	420	224	7
2. Shldr. lat/med.	1444	644	420	224	7
3. Hip flex/knee/ankle	484	184	120	64	2
4. Hip abd	260	60	60	0	1
5. Waist flex	398	198	120	78	2
6. Side/side waist	398	198	120	78	2
7. Flex/ext shldr	1444	644	420	224	7
8. Arm bearing	1444	644	420	224	7
9. Elbow flexions	3200	1500	960	650	16
10. Rotation waist	350	150	120	30	2
11. Boot	300	100	60	40	1
12. Knee	300	100	60	40	1

REPEAT SEQUENCE 60 TIMES

SEQUENCE V-C	TOTAL CYCLES REQUIRED VENT.	TOTAL CYCLES REMAINING AT START OF THIS SEQUENCE	TOTAL CYCLES THIS SEQUENCE	TOTAL REMAINING AT SEQUENCE COMPLETION	NUMBER OF CYCLES
1. Shoulder ab/ad	1444	224	240	0	6
2. Shldr. lat/med.	1444	224	240	0	6
3. Hip flex/knee/ankle	484	64	80	0	2
4. Hip abd	260	0	0	0	n/a
5. Waist flex	398	78	80	0	2
6. Side/side waist	398	78	80	0	2
7. Flex/ext shldr	1444	224	240	0	6
8. Arm bearing	1444	224	240	0	6
9. Elbow flexions	3200	650	680	0	17
10. Rotation waist	350	30	40	0	1
11. Boot	300	40	40	0	1
12. Knee	300	40	40	0	1

REPEAT SEQUENCE 40 TIMES

	SEQUENCE P-A	TOTAL CYCLES REQUIRED PRESS.	TOTAL CYCLES REMAINING AT START OF THIS SEQUENCE	TOTAL CYCLES THIS SEQUENCE	TOTAL REMAINING AT SEQUENCE COMPLETION	NUMBER OF CYCLES
1.	Shoulder ab/ad	13,020	13,020	7,200	5,820	8
2.	Shldr. lat/med.	13,020	13,020	7,200	4,820	5
3.	Hip flex/knee/ankle	4,356	4,356	2,700	1,656	3
4.	Hip abd	2,360	2,360	1,800	560	2
5.	Waist flex	3,834	3,834	1,800	2,034	2
6.	Side/side waist	3,834	3,834	1,800	2,034	2
7.	Flex/ext shldr	13,020	13,020	7,200	5,820	8
8.	Arm bearing	13,020	13,020	7,200	5,820	8
9.	Elbow flexions	29,020	29,020	15,300	13,720	17
10.	Rotation waist	3,130	3,130	1,800	1,330	2
11.	Boot	2,700	2,700	1,800	900	2
12.	Knee	2,740	2,740	1,800	940	2

REPEAT SEQUENCE 900 TIMES

SEQUENCE P-B	TOTAL CYCLES REQUIRED PRESS.	TOTAL CYCLES REMAINING AT START OF THIS SEQUENCE	TOTAL CYCLES THIS SEQUENCE	TOTAL REMAINING AT SEQUENCE COMPLETION	NUMBER OF CYCLES
1. Shoulder ab/ad	13,020	5,820	3,780	2,040	7
2. Shldr. lat/med	13,020	5,820	3,780	2,040	7
3. Hip flex/knee/ankle	4,356	1,656	1,080	576	2
4. Hip abd	2,360	560	540	20	1
5. Waist flex	3,834	2,034	1,080	954	2
6. Side/side waist	3,834	2,034	1,080	954	2
7. Flex/ext shldr	13,020	5,820	3,780	2,040	7
8. Arm bearing	13,020	5,820	3,780	2,040	7
9. Elbow flexions	29,020	13,720	8,640	5,080	16
10. Rotation waist	3,130	1,330	1,080	250	2
11. Boot	2,700	900	540	360	1
12. Knee	2,740	940	540	400	1

REPEAT SEQUENCE 540 TIMES

	SEQUENCE P-C	TOTAL CYCLES REQUIRED PRESS.	TOTAL CYCLES REMAINING AT START OF THIS SEQUENCE	TOTAL CYCLES THIS SEQUENCE	TOTAL REMAINING AT SEQUENCE COMPLETION	NUMBER OF CYCLES
1.	Shoulder ab/ad	13,020	2,040	2,040	0	6
2.	Shldr. lat/med.	13,020	2,040	2,040	0	6
3.	Hip flex/knee/ankle	4,356	576	680	0	2
4.	Hip abd	2,360	20	0	20	0
5.	Waist flex	3,834	954	680	274	2
6.	Side/side waist	3,834	954	680	274	2
7.	Flex/ext shldr	13,020	2,040	2,040	0	6
8.	Arm bearing	13,020	2,040	2,040	0	6
9.	Elbow flexions	29,020	5,080	5,100	0	15
10.	Rotation waist	3,130	250	0	250	0
11.	Boot	2,700	360	340	20	1
12.	Knee	2,740	400	340	60	1

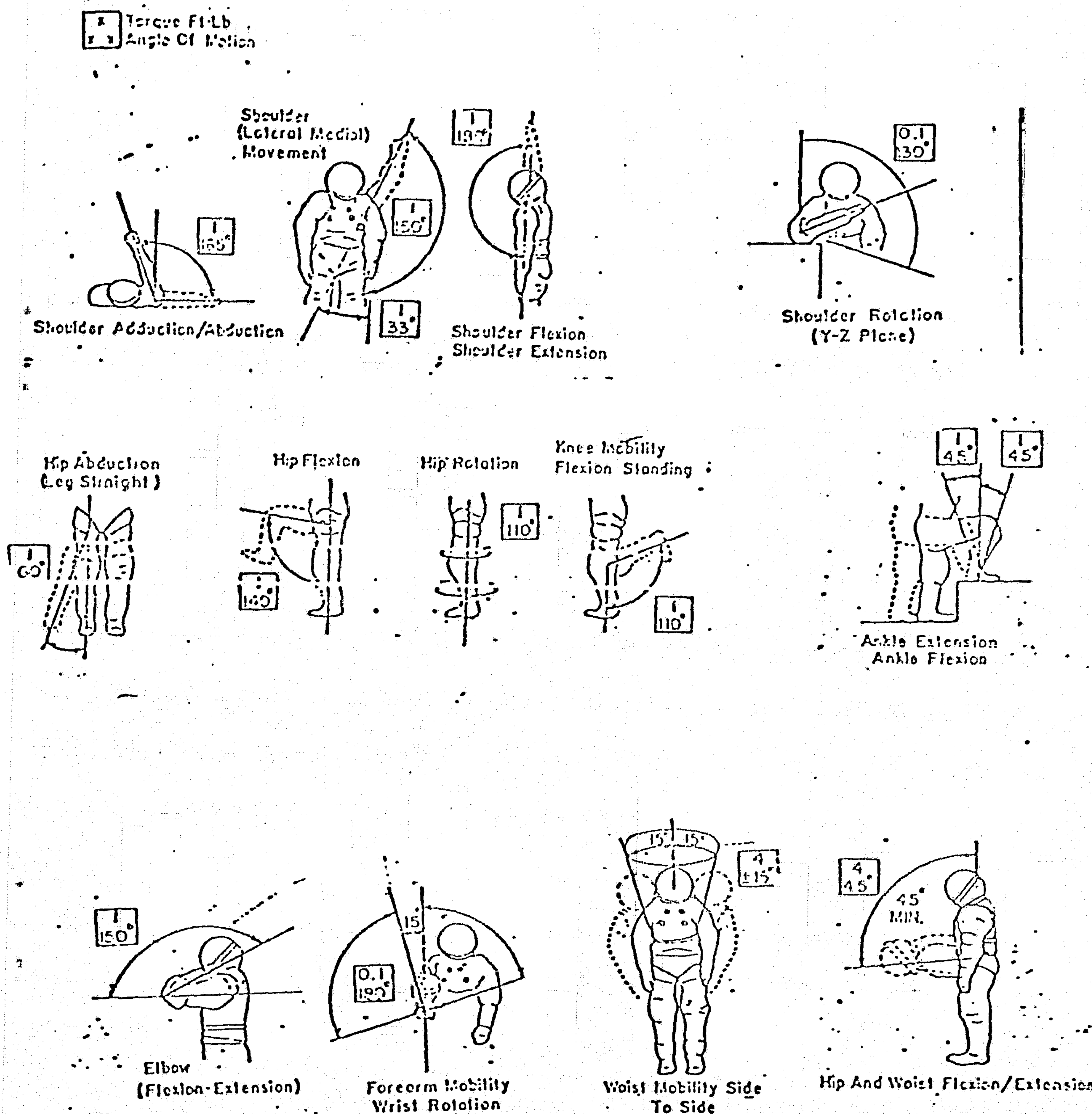
REPEAT SEQUENCE 340 TIMES

SEQUENCE P-D	TOTAL CYCLES REQUIRED PRESS.	TOTAL CYCLES REMAINING AT START OF THIS SEQUENCE	TOTAL CYCLES THIS SEQUENCE	TOTAL REMAINING AT SEQUENCE COMPLETION	NUMBER OF CYCLES
1. Shoulder ab/ad	13,020	0	0	0	0
2. Shldr. lat/med.	13,020	0	0	0	0
3. Hip flex/knee/ankle	4,356	0	0	0	0
4. Hip abd	2,360	20	30	0	2
5. Waist flex	3,834	274	285	0	19
6. Side/side waist	3,834	274	285	0	19
7. Flex/ext shldr	13,020	0	0	0	0
8. Arm bearing	13,020	0	0	0	0
9. Elbow flexions	29,020	0	0	0	0
10. Rotation waist	3,130	250	255	0	17
11. Boot	2,700	20	30	0	2
12. Knee	2,740	60	60	0	4

REPEAT SEQUENCE 15 TIMES

ATTACHMENT II

MOVEMENT DESCRIPTIONS



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